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**FINAL**

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROJECT PLANS  
OPERABLE UNIT 19  
SITE 84/BUILDING 45 AREA**

**MARINE CORPS BASE  
CAMP LEJEUNE, NORTH CAROLINA**

**CONTRACT TASK ORDER 0139 (CLEAN II)**

**JUNE 2001**

*Prepared for:*

**DEPARTMENT OF THE NAVY  
NAVAL FACILITIES  
ENGINEERING COMMAND ATLANTIC DIVISION  
*Norfolk, Virginia***

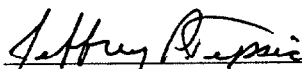
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**LANTDIV CLEAN II Program  
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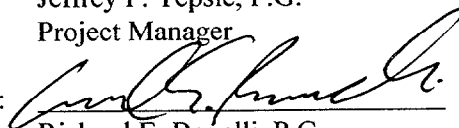
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**For:**

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NAVAL FACILITIES ENGINEERING COMMAND  
ATLANTIC DIVISION  
*Norfolk, Virginia***

**Through:**

**CH2M HILL Federal Group, Ltd.**

**FINAL**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY**  
**WORK PLAN**  
**SITE 84/BUILDING 45 AREA**  
**MCB CAMP LEJEUNE, NORTH CAROLINA**  
**CONTRACT TASK ORDER 0139 (CLEAN II)**  
**JUNE 2001**

*Prepared for:*

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## TABLE OF CONTENTS

	<u>Page</u>
<b>1.0 INTRODUCTION.....</b>	<b>1-1</b>
1.1 Objective of RI/FS Work Plan .....	1-1
1.2 RI/FS Scoping .....	1-1
1.3 Work Plan Organization .....	1-2
<b>2.0 BACKGROUND AND SETTING .....</b>	<b>2-1</b>
2.1 Marine Corps Base, Camp Lejeune.....	2-1
2.1.1 Location and Setting.....	2-1
2.1.2 History and Mission .....	2-3
2.1.3 Topography and Surface Drainage.....	2-3
2.1.4 Regional Geology.....	2-4
2.1.5 Regional Hydrogeology .....	2-4
2.1.6 Surface Water Hydrology.....	2-6
2.1.7 Climatology.....	2-6
2.1.8 Water Supply.....	2-7
2.1.9 Ecological Characteristics.....	2-7
2.1.10 Wetlands.....	2-10
2.1.11 Threatened and Endangered Species.....	2-10
2.1.12 Land Use .....	2-11
2.2 Site 84/Building 45 Area.....	2-12
2.2.1 Site Location and Setting .....	2-12
2.2.2 Site History.....	2-12
2.2.3 Site Geology and Hydrogeology .....	2-12
2.2.4 Previous Investigations and Findings.....	2-13
2.2.5 Conclusions From Previous Investigations .....	2-15
<b>3.0 DATA QUALITY AND SAMPLING OBJECTIVES.....</b>	<b>3-1</b>
3.1 Data Quality Objectives Process .....	3-1
3.1.1 Step 1 - State the Problem .....	3-2
3.1.2 Step 2 - Identify the Decision .....	3-2
3.1.3 Step 3 - Identify the Inputs to the Decision.....	3-3
3.1.4 Step 4 - Define the Boundaries of the Study .....	3-3
3.1.5 Step 5 - Develop a Decision Rule .....	3-4
3.1.6 Step 6 - Specify Tolerable Limits on Decision Errors .....	3-4
3.1.7 Step 7 - Optimize the Design for Obtaining Data .....	3-4
<b>4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS.....</b>	<b>4-1</b>
4.1 Task 1 - Project Management.....	4-1
4.2 Task 2 - Subcontract Procurement.....	4-1
4.3 Task 3 - Field Investigations.....	4-1
4.4 Task 4 - Sample Analysis and Validation.....	4-2
4.5 Task 5 - Data Evaluation .....	4-3
4.6 Task 6 - Risk Assessment.....	4-3
4.6.1 Human Health Evaluation Process.....	4-5
4.6.1.1 Site Location and Characterization.....	4-5
4.6.1.2 Data Summary .....	4-5
4.6.1.3 Identifying Chemicals of Potential Concern.....	4-6
4.6.1.4 Exposure Assessment .....	4-6

# **TABLE OF CONTENTS** (Continued)

	<u>Page</u>
4.6.1.5 Toxicity Assessment.....	4-8
4.6.1.6 Risk Characterization .....	4-9
4.6.1.7 Uncertainty Analysis .....	4-10
4.6.2 Ecological Risk Assessment.....	4-10
4.6.2.1 Step 1 – Screening-Level Problem Formulation and Ecological Effects Evaluation .....	4-11
4.6.2.2 Step 2 - Screening-level Preliminary Exposure Estimate and Risk .....	4-11
4.6.2.3 Step 3a – Refinement of the List of Chemicals of Potential Concern .....	4-12
4.6.2.4 Risk Characterization .....	4-13
4.6.2.5 Uncertainty Analysis .....	4-13
4.7 Task 7 – Remedial Investigation Report .....	4-13
4.8 Task 8 – Remedial Alternatives Screening .....	4-14
4.9 Task 9 – Remedial Alternatives Evaluation .....	4-14
4.10 Task 10 - Feasibility Study Report.....	4-14
4.11 Task 11 – Post RI/FS Support .....	4-14
4.12 Task 12 – Meetings .....	4-14
 <b>5.0 PROJECT MANAGEMENT AND STAFFING .....</b>	 <b>5-1</b>
 <b>6.0 SCHEDULE .....</b>	 <b>6-1</b>
 <b>7.0 REFERENCES .....</b>	 <b>7-1</b>



## TABLE OF CONTENTS

*(Continued)*

### LIST OF TABLES

- 2-1 Geologic and Hydrogeologic Units in the Coastal Plain of North Carolina
- 2-2 Climatic Data Summary, Marine Corps Air Station, New River
- 2-3 Hydraulic Property Estimates of the Castle Hayne Aquifer and Confining Unit
- 2-4 Protected Species
- 2-5 Land Utilization: Developed Areas Land Use
- 2-6 Summary of Previous Investigation Results
  - 2-6A ATEC Associates, Inc., 1992
  - 2-6B O'Brien and Gere, 1992
  - 2-6C R.E. Wright Associates, Inc., 1994
  - 2-6D Law Engineering, Inc., 1994
  - 2-6E Baker Environmental, Inc., 1998
  - 2-6F J.A. Jones Environmental Services, Inc., 1999
  - 2-6G Baker Environmental, Inc., 1999
- 3-1 Site 84/Building 45 Area RI/FS Objectives
- 4-1 Summary of Sampling Analytical Objectives

### LIST OF FIGURES

- 1-1 Site Location Map
- 2-1 Potable Water Supply Wells Within a One-Mile Radius of Site 84
- 2-2 Site Map
- 2-3 Previous Investigations Sample Location Map
- 2-4 Estimated Area of Concern, Detected PCBs Greater Than 320  $\mu\text{g/kg}$   
Pre-RI Screening Study (Baker, 1998)
- 2-5 Estimated Area of Concern, Detected PCBs Greater Than 25,000  $\mu\text{g/kg}$   
Pre-RI Screening Study (Baker, 1998)
- 2-6 Organics Detected in Groundwater  
Pre-RI Screening Study (Baker, 1998)
- 2-7 PCBs Detected in Sediments  
Pre-RI Screening Study (Baker, 1998)
- 5-1 Project Organization
- 6-1 Project Schedule

## LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
Baker	Baker Environmental, Inc.
BDL	below detection limit
bgs	below ground surface
BRA	baseline risk assessment
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
COPC	Contaminant of Potential Concern
CPG	Certified Professional Geologist
DEM	Department of Environmental Management
DoN	Department of the Navy
DQO	Data Quality Objective
DRO	diesel range organics
EDI	Estimated Daily Intake
EMD	Environmental Management Division (Camp Lejeune)
ESE	Environmental Science and Engineering, Inc.
°F	degrees Fahrenheit
FFA	Federal Facilities Agreement
FMFLANT	Fleet Marine Force Atlantic
FSAP	Field Sampling and Analysis Plan
FSSG	Force Service Support Group
ft/d	feet per day
ft <sup>2</sup> /d	square feet per day
FWQC	Federal Water Quality Criteria
FY	Fiscal Year
gpd	gallons per day
gpd/ft	gallon per day per foot
gpm	gallons per minute
GRO	gasoline range organics
GSRA	Greater Sandy Run Area
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HQ	hazard quotient

## LIST OF ACRONYMS AND ABBREVIATIONS

*(Continued)*

IAS	Initial Assessment Study
IDW	Investigation Derived Waste
IRIS	Integrated Risk Information System
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LOAEL	little-observed-adverse-effect-level
MAGTF	Marine Air Ground Task Force
MCAS	Marine Corps Air Station
MCB	Marine Corps Air Station
MCL	maximum contaminant level
mgd	million gallons per day
mg/kg	milligram per kilogram
mg/kg-d	milligram per kilogram per day
mg/L	milligram per liter
msl	mean sea level
NCDEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCWQS	North Carolina Water Quality Standard
NFESC	Naval Facilities Engineering Service Center
NOAA	National Oceanic Atmosphere Administration
NOAEL	no-observed-adverse-effect-level
NPL	National Priorities List
NREA	Natural Resources and Environmental Affairs
NWI	National Wetland Inventory
PCB	polychlorinated biphenyl
PE	Professional Engineer
PG	Professional Geologist
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PRGs	Preliminary Remediation Goals
q1*	carcinogenic slope factor
QAPP	Quality Assurance Project Plan
RAGS	Remedial Action Standards
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RfD	reference dose
RI	Remedial Investigation
RI/FS	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPM	Remedial Project Manager

## LIST OF ACRONYMS AND ABBREVIATIONS

*(Continued)*

SARA	Superfund Amendments and Reauthorization Act
SSV	Sediment Screening Value
TAL	Target Analyte List
TCL	Target Compound List
TPH	Total Petroleum Hydrocarbons
TRC	Technical Review Committee
$\mu\text{g/L}$	micrograms per liter
$\mu\text{g/kg}$	micrograms per kilogram
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USDI	U.S. Department of the Interior
USDOA	U.S. Department of Agriculture
UST	underground storage tank
WAR	Water and Air Research
WOE	weight-of-evidence
WQS	Water Quality Standard



## **1.0 INTRODUCTION**

Marine Corps Base (MCB), Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment and Natural Resources (NCDENR), and the United States Department of the Navy (DoN) entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect the public health, welfare and the environment (FFA, 1989).

The scope of the FFA included the implementation of a Remedial Investigation/Feasibility Study (RI/FS) at previously identified sites throughout the MCB, Camp Lejeune. Since being placed on the NPL and entering into the FFA, additional sites have been identified at the MCB that have required RI/FSs. Remedial Investigations have been implemented to assess the nature and extent of the threat to the public health and welfare, or to the environment caused by the release and/or threatened release of hazardous substances, pollutants, contaminants or constituents at the site and to establish requirements for the performance of feasibility studies. Feasibility studies will be conducted to identify, evaluate, and select alternatives for the appropriate CERCLA responses to prevent, mitigate, or abate the release or threatened release of hazardous substances, pollutants, contaminants, or constituents at the site in accordance with CERCLA/Superfund Amendments and Reauthorization Act (SARA) and applicable state law (FFA, 1989).

This RI/FS Work Plan has been prepared by Baker Environmental, Inc. (Baker) and addresses Site 84/Building 45 Area.

### **1.1 Objective of RI/FS Work Plan**

The objective of this RI/FS Work Plan is to identify the tasks required to implement an RI/FS for Site 84 at MCB, Camp Lejeune. Figure 1-1 shows the location of Site 84 within MCB Camp Lejeune. The Work Plan documents the scope and objectives of the individual RI/FS activities required to collect the appropriate data. It will serve as a tool for assigning responsibilities and establishing the project schedule and cost. The preparation and contents of the RI/FS Work Plan are based on the scoping process, which is described below.

### **1.2 RI/FS Scoping**

Scoping is the initial planning stage of the RI/FS and of site remediation. The result or outcome of the scoping process is documented in the RI/FS. Scoping begins once the background information is reviewed and evaluated, and consists of the following:

- Assessing the potential for human health and/or environmental risks.
- Identifying interim actions to mitigate immediate potential threats to the public health and the environment.
- Identifying potential contaminant migration pathways.
- Identifying contaminants of concern
- Identifying Federal and State Applicable or Relevant and Appropriate Requirements (ARARs).

- Identifying potential technologies/alternatives for mitigating site problems.
- Determining the type, amount, and data quality objectives (DQOs) to assess human health and environmental risks, and to effectively evaluate feasible technologies/alternatives.
- Identifying the remedial alternatives apparently suitable to site conditions.

The background information available for this process included existing environmental assessment reports, which are identified in Section 7.0 (References), and information collected during planning visits to the site.

As part of the scoping process, project meetings were conducted with the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), MCB Camp Lejeune, USEPA Region IV, and the NCDENR to discuss the proposed RI/FS scope of work for Site 84, and to obtain technical and administrative input from LANTDIV.

Underground storage tanks (USTs) have been identified at the site. The USTs contained fuels and have been removed or closed. Previous investigations and tank removals have identified fuel-related contamination. Removal actions have been implemented. Based on the fact that site USTs have been addressed, nature and extent of contamination determined and removal actions implemented, as appropriate, fuel-related constituents are not a subject of this RI/FS.

### **1.3 Work Plan Organization**

The following sections comprise the Work Plan:

- Section 1.0 Introduction
- Section 2.0 Background and Setting
- Section 3.0 Data Quality Objectives
- Section 4.0 Remedial Investigation/Feasibility Study Tasks
- Section 5.0 Project Management and Staffing
- Section 6.0 Schedule
- Section 7.0 References

Section 2.0 documents the evaluation of background information, along with the location and setting of the site. The purposes of this section is to define the physical and known environmental characteristics of the site. This section focuses on identifying potential and/or confirmed contaminant migration pathways, identifying potential (or known) impacts to public health and environment, listing Federal or State ARARs, and evaluating potential remedial technologies/alternatives for mitigating site problems.

Section 3.0 defines site-specific RI/FS data quality objectives. Data or information deemed necessary to identify migration pathways, assess environmental and human health risks, or evaluate feasibility or remedial actions are presented in this section. This data may consist of chemical analyses, hydrogeologic information, or engineering analyses. The collection methods for obtaining this information are also identified and described in general terms [more detailed descriptions of the field investigation activities are documented in the Field Sampling and Analysis Plan (FSAP)].

Section 4.0 identifies and describes the tasks and field investigation activities that will be implemented to complete the RI/FS in terms of meeting the site-specific objectives. These tasks generally follow the description of tasks identified in USEPA's RI/FS Guidance Document (OSWER Directive 955.3-01).

Section 5.0 discusses project management and staffing for implementing the RI/FS. The RI/FS schedule is provided in Section 6.0. References used in developing the RI/FS Work Plan are provided in Section 7.0.

## **2.0 BACKGROUND AND SETTING**

The purpose of this section is to summarize and evaluate existing information pertaining to MCB, Camp Lejeune and Site 84. The analysis of existing information will serve to provide an understanding of the nature and extent of contamination in order to aid in the design of the RI tasks.

This section specifically addresses the location and setting of the site, historical events associated with past usage or disposal activities, topography and surface drainage, regional geology and hydrogeology, site-specific geology and hydrogeology, surface water hydrology, climatology, natural resources and ecological features, and land use.

Additional information can be found in the following documents:

- Initial Assessment Study (IAS) of Marine Corps Base Camp Lejeune, North Carolina (Water and Air Research, 1983)
- Final Site Summary Report, Marine Corps Base, Camp Lejeune (Environmental Science and Engineering, Inc. 1990)
- UST Site Check Investigation Report, Building 45 (ATEC, 1991)
- UST Investigation (O'Brien and Gere, 1992)
- Leaking Underground Storage Tank Site Assessment Report, Building 45, UST S-942-2, Marine Corps Base, Camp Lejeune, North Carolina (Law Engineering and Environmental Services, Inc 1994)
- Pre-Remedial Investigation Screening Study Report (Baker Environmental, Inc., 1998)
- Hydrogeology of Aquifers in Cretaceous and Younger Rocks in the Vicinity of Onslow and Southern Jones Counties, North Carolina (U.S. Geological Survey, 1990)
- Continuous Seismic Reflection Profiling of Hydrogeologic Features Beneath New River, Camp Lejeune, North Carolina (U.S. Geological Survey, 1989)

### **2.1 Marine Corps Base, Camp Lejeune**

This section provides an overview of the physical features associated with MCB, Camp Lejeune.

#### **2.1.1 Location and Setting**

MCB, Camp Lejeune is located within the Coastal Plain Physiographic Province. It is located in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington. The facility covers approximately 236 square miles. This includes the recent acquisition of approximately 64 square miles west of the facility within the Greater Sandy Run Area (GSRA) of the county. The military reservation is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean.



The eastern border of MCB, Camp Lejeune is the Atlantic shoreline. The western and northwestern boundaries are U.S. Route 17 and State Route 24, respectively. The City of Jacksonville, North Carolina borders MCB, Camp Lejeune to the north. The location of MCB, Camp Lejeune is depicted in Figure 1-1.

The GSRA is located in the southeast portion of Onslow County, North Carolina, near the Pender-Onslow County border. The GSRA is approximately 31 miles northeast of Wilmington, North Carolina; 15 miles south of Jacksonville, North Carolina; and 5 miles northwest of the Atlantic Ocean. The GSRA is located south and west of MCB, Camp Lejeune, sharing a common boundary along Route 17 between Dixon, North Carolina and Verona, North Carolina.

The following overview of the Base was taken from the document "Master Plan, Camp Lejeune Complex, North Carolina." The Complex consists of 12 identifiable developed areas. Of the developed areas, Hadnot Point comprises the most concentrated area of development. This area includes the organizational offices for the Host Activity and for the Headquarters, 26th Marine Amphibious Unit, as well as the Headquarters and regimental areas for the 2nd Marine Division, Marine Expeditionary Force, 6th Marine Expeditionary Brigade, 22nd Marine Expeditionary Unit, 24th Marine Amphibious Unit, the Central Exchange & Commissary and the Naval Dental Clinic Headquarters. Directly north of Hadnot Point are the family housing areas concentrated throughout the wooded areas of the central Complex and along the shores of the New River. Also located in this north central area are major personnel support land uses, including the newly-constructed Naval Hospital, school sites, recreational areas, as well as additional family housing areas (quarters developments, Midway Park and Tarawa Terrace I and II).

MCAS New River and Camp Geiger are considered as a single urban area possessing two separate missions and supported by two unrelated groups of personnel. MCAS New River encompasses 2,772 acres and is located in the northwestern section of the Base and lies approximately five miles south of Jacksonville. The MCAS includes air support activities, troop housing and personnel support facilities, all of which immediately surround the aircraft operations and maintenance areas.

Camp Geiger, located directly north of MCAS New River, contains a mixture of troop housing, personnel support and training uses. Currently, the area is utilized by a number of groups which have no direct relationship to one another. The majority of the land surrounding this area is comprised of buffer zones and undevelopable marshland.

MCB, Camp Lejeune contains five other areas of concentrated development, all of which are much smaller in size and population than either Hadnot Point, MCAS New River, or the Camp Geiger area. The oldest of these is the Montford Point area, which is bounded by the New River to the south and west, and by Route 24 on the north. New development in Montford Point has been limited, with most of the facilities for troop housing, maintenance, supply and personnel support having been converted from their intended uses. A majority of the MCB training schools requiring classroom instruction are located here and use surrounding undeveloped areas for training operations when required. The French Creek area located directly south of Hadnot Point is occupied by the 2nd Force Service Support Group (2nd FSSG). Its activities are directed toward providing combat service and technical support as required by Headquarters, II Marine Expeditionary Force. Expansion of the French Creek Complex is constrained by the Ordnance Storage Depot explosives safety arc on the south and by the regimental area of Hadnot Point. Onslow Beach, located along the Onslow Bay, east of the New River Inlet, presents assets for amphibious training as well as recreational use. Courthouse Bay is located on one of a series of small bays which are formed by the New River. This area is used for maintenance, storage and training associated with amphibious vehicles and heavy engineering equipment. The Engineering

School, also located here, conducts training activities in the large open area located to the southeast of the Courthouse Bay. Another concentrated area of development is the Rifle Range. This area is located on the southwest side of the New River, is singular in purpose and has only a small number of assigned personnel. It was constructed in the early stages of Base development and is used solely for rifle qualification training. The small group of barracks, located at the Rifle Range, are used for two-week periods by troops assigned to range training.

### **2.1.2 History and Mission**

Construction of MCB, Camp Lejeune began in 1941 with the objective of developing the "World's Most Complete Amphibious Training Base." Construction of the Base started at Hadnot Point, where the major functions of the base are centered. Development at MCB, Camp Lejeune is primarily in five geographical locations under the jurisdiction of the Base Command. These areas include Camp Geiger, Montford Point, Courthouse Bay, Mainside, and the Rifle Range Area.

The MCB organization functions as the host command to the two Fleet Marine Force Atlantic (FMFLANT) tenant activities -- Headquarters of the II Marine Expeditionary Division and the 2nd FSSG. The MCB host organization mission is to provide housing, training facilities, logistical support and certain administrative support for tenant units and for other units assigned to MCB, Camp Lejeune and to conduct specialized schools and other training maneuvers, as directed.

The mission of the 6th Marine Expeditionary Brigade is to provide the Command element for a brigade-size Marine Air Ground Task Force (MAGTF).

The mission of the 2nd Marine Division is to execute amphibious assault operations, and other operations as may be directed, which are supported by Marine aviation and force service support units. With the aircraft wing, the Marine division provides combined arms for service with the Fleet in the seizure or defense of advanced naval bases and for the conduct of land operations essential to the prosecution of a naval campaign.

The mission of the 2nd FSSG is to command, administer and train assigned units in order to provide combat service and technical support as required by Headquarters FMFLANT and its subordinate command in accomplishment of the overall FMFLANT mission.

### **2.1.3 Topography and Surface Drainage**

The generally flat topography of MCB, Camp Lejeune is typical of the seaward portions of the North Carolina Coastal Plain. Elevations on the Base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of Camp Lejeune is between 20 and 40 feet msl.

Drainage at Camp Lejeune is generally toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of Camp Lejeune is in broad, flat interstream areas. Drainage is poor in these areas and the soils are often wet. (Water and Air Research, 1983).

The U.S. Army Corps of Engineers has mapped the limits of the 100-year floodplain at Camp Lejeune at 7.0 feet above msl in the upper reaches of the New River (Water and Air Research, 1983); this increases downstream to 11 feet above msl near the coastal area (Water and Air Research, 1983). Site 84 does not lie within the 100-year floodplain of the New River.

#### 2.1.4 Regional Geology

MCB, Camp Lejeune is within the Tidewater region of the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist mostly of interbedded sands, silts, clays, calcareous clays, shell beds, sandstone and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast to a combined thickness of approximately 1,500 feet. They were deposited in marine or near-shore environments and range in age from early Cretaceous to Quaternary time. Regionally, the sediments comprise 10 aquifers and nine confining units which overlie igneous and metamorphic basement rocks of the pre-Cretaceous age. Seven of these aquifers and their associated confining units are present in the MCB, Camp Lejeune area (Cardinell, et al., 1993). Table 2-1 presents a generalized stratigraphic column for Jones and Onslow Counties, North Carolina. Hydrogeologic section location plan and hydrogeologic cross-sections of the MCB, Camp Lejeune area are presented in the Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina (Cardinell, et al, 1993).

#### 2.1.5 Regional Hydrogeology

The following paragraphs discuss the hydrogeologic conditions at MCB, Camp Lejeune. The information presented within this section is from literature published by the United States Geological Survey (USGS) (Harned, et al., 1989 and Cardinell, et al., 1993). Additionally, information was collected from a technical memorandum prepared by Baker summarizing groundwater data and aquifer characteristics for MCB, Camp Lejeune (see Appendix B).

USGS studies at MCB, Camp Lejeune indicate that the area is underlain by sand and limestone aquifers separated by confining units of silt and clay. These aquifers include the surficial (water table), Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear. Less permeable clay and silt beds function as confining units or semi-confining units which separate the aquifers and impede the flow of groundwater between aquifers.

The surficial unit consists of interfingering beds of sand, clay, sandy clay and silt that contain some peat and shells of Quaternary and Miocene age. These sediments commonly extend to depths of 50 to 100 feet below ground surface (bgs). Thickness of the surficial aquifer in the MCB, Camp Lejeune area ranges from zero to 73 feet, and typically average 25 feet (Cardinell, et al., 1993). The aquifer is generally thickest in the interstream divide areas and may be absent where it is cut by the New River and its tributaries. The clay, sandy clay, and silt beds that occur in the surficial aquifer are thin and discontinuous throughout. A semi-confining unit is found in the surficial aquifer within some portions of MCB, Camp Lejeune.

Recharge to the surficial aquifer is by rainfall. The aquifer receives more recharge in the winter than in the summer when much of the water evaporates or is transpired by plants before it can reach the water table. Most of the surficial groundwater is discharged to local streams, but some water passes through the underlying semiconfining unit. Recharge for the surficial aquifer is based on an average rainfall of 52 inches per year and an average recharge of 30 percent, or an annual recharge of approximately 16 inches per year (Table 2-2). The remaining 70 percent of the rainfall is lost as surface runoff or evapotranspiration. Sixteen inches of recharge equates to 7,600,000 gallons per day (gpd) per square mile or approximately 114,000,000 gpd for all of MCB, Camp Lejeune (based on 150 square miles of recharge area). Water levels in the wells tapping the surficial aquifer vary seasonally. The water table is generally highest in the winter and spring, and lowest in the summer and early fall. The estimated lateral hydraulic conductivity for the surficial aquifer is 50 feet per day (ft/d) and is based on a general composition of fine sand mixed with some silt and clay (Cardinal, et al., 1993).

A study of data from aquifer tests (pump tests) done at MCB, Camp Lejeune was conducted by Baker in 1994 to evaluate aquifer characteristics and production capacities. The technical memorandum is provided in Appendix B. The information contained in this memorandum pertains primarily to the surficial aquifer. Average pumping rates were established between 0.5 to three gallons per minute (gpm); transmissivity ranged from 7.1 to 7,100 square feet per day ( $\text{ft}^2/\text{day}$ ); storativity ranged from  $1.5 \times 10^3$  to  $7.5 \times 10^2$ ; and hydraulic conductivity was estimated to range from 0.5 to 1.4 ft/day.

Although the aquifer is classified as GA (i.e., existing or a potential source of drinking water supply for humans), it is not used as a potable water source at MCB, Camp Lejeune because of its low yielding production rates (typically less than three gpm).

The Castle Hayne confining unit is composed of silt, clay and sandy clay beds. These beds form a unit across MCB, Camp Lejeune that may be represented by one or more geological units such as the deposits at the bottom of the surficial aquifer, the uppermost beds of the River Bend Formation or the uppermost beds of the Castle Hayne Formation. Overall, the Castle Hayne confining unit may be characterized as a group of less permeable beds at the top of the Castle Hayne aquifer that have been eroded in places. The thickness of the confining unit ranges from zero to 26 feet thick, averaging nine feet thick where present. No discernible trend in the thickness of the confining unit exists although it is more than 20 feet thick only in the southern and southwestern parts of the Base. The vertical hydraulic conductivity of the Castle Hayne confining unit was estimated to range from 0.0014 to 0.41 ft/d. These values are comparable to those determined for silts and clays and, therefore, this unit may only be partly effective at retarding the vertical movement of groundwater between the surficial and Castle Hayne aquifers (Cardinell, et al., 1993).

The principal water supply aquifer for MCB, Camp Lejeune is the Castle Hayne aquifer. This aquifer primarily resides within the River Bend Formation which consists of sand, cemented shells and limestone. The upper portion of the aquifer primarily consists of calcareous sands with some thin clay and silt beds. The sand becomes increasingly more limy with depth. The lower portion of the aquifer consists of partially unconsolidated limestone and sandy limestone interbedded with clay and sand. Also, buried paleostream channels containing various deposits exist within the aquifer. The top of the aquifer ranges from 10 feet above msl to 70 feet below msl and is irregular over most of the northern portion of MCB, Camp Lejeune. The aquifer is more regular in areas southeast of the New River, where it slopes southeastward. The Castle Hayne thickens to the east, from 160 feet in the Camp Geiger area to more than 400 feet at the eastern boundary of MCB, Camp Lejeune.

Estimated transmissivity, hydraulic conductivity and storage coefficient values (unitless) for the Castle Hayne aquifer range from 6,100 to 183,300 gpd/ft, 14 to 91 ft/d and  $2 \times 10^{-4}$  to  $1.9 \times 10^{-3}$ , respectively. An aquifer pump test conducted by ESE (1988) in the Hadnot Point Industrial Area, using an existing water supply well (HP642), indicates an average transmissivity and storage coefficient of 9,600 gpd/ft and  $8.8 \times 10^{-4}$ , respectively (ESE, 1988). Table 2-3 summarizes the previously stated information.

Recharge of the Castle Hayne aquifer at MCB, Camp Lejeune is primarily received from the surficial aquifer. Natural discharge is to the New River and its major tributaries. The Castle Hayne aquifer provides roughly seven million gallons of water per day to MCB, Camp Lejeune. Groundwater pumping has not significantly affected natural head gradients in the aquifer.



MCB, Camp Lejeune lies in an area where the upper part of the Castle Hayne aquifer contains freshwater. Saltwater is found in the bottom of the aquifer in the region and in the New River estuary; both are of concern in managing water withdrawals from the aquifer. Over pumping the deeper parts of the aquifer or in areas hydraulically connected to estuarine streams could cause saltwater intrusions. The aquifer underlying most of the area contains water having less than 120 milligrams per liter (mg/L) of chloride.

#### **2.1.6 Surface Water Hydrology**

The following summary of surface water hydrology was originally presented in the Initial Assessment Study (IAS) report (WAR, 1983).

The dominant surface water body at MCB, Camp Lejeune is the New River. It receives drainage from most of the Base. The river is short, with a course of approximately 50 miles on the central Coastal Plain of North Carolina. Over most of its course, the New River is confined to a narrow channel entrenched in Eocene and Oligocene limestones. South of Jacksonville, the river widens as it flows across less resistant sands, clays, and marls. At MCB, Camp Lejeune, the New River flows in a southerly direction into the Atlantic Ocean through the New River Inlet. Several small coastal creeks that are not associated with the New River or its tributaries drain into the area of MCB, Camp Lejeune. The New River, the Intracoastal Waterway and the Atlantic Ocean converge at the New River Inlet.

Classifications for surface waters in North Carolina have been published under Title 15 of the North Carolina Administration Code. At MCB, Camp Lejeune, the New River falls into three classifications. The portion of the river that passes from the Seaboard Coast Line railroad trestle (located south/southwest of where U.S. Route 17/North Carolina Route 24 crosses the New River) to Montford Point is classified as SC NSW HQW. This classification is defined as salt waters protected for secondary recreation, fishing, aquatic life including propagation and survival (SC) that are nutrient sensitive (NSW) and of high quality (HQW). The portion of the river that resided between Montford Point to a line extending across the river from Grey Point to a point of land approximately 2,200 yards downstream of the mouth of Duck Creek is classified as Class SC NSW. As previously described, these waters are similar to the waters upstream of Montford Point, however they are not considered high quality waters. The remaining portion of the New River is classified as estuarine water suited for commercial shell fishing and all other tidal saltwater uses (SA).

#### **2.1.7 Climatology**

Although coastal North Carolina lacks distinct wet and dry seasons, there is some seasonal variation in average precipitation (see Table 2-2). July receives the most precipitation and rainfall amounts during summer are generally the greatest. Daily showers during the summer are common, and so are periods of one or two weeks without rain. Convective showers and thunderstorms contribute to the variability of precipitation during the summer months. October receives the least amount of precipitation, on average. Throughout the winter and spring months precipitation occurs primarily as migratory low pressure storms. MCB, Camp Lejeune's average yearly rainfall is approximately 52 inches. Table 2-2 presents a climatic summary of data collected during 35 years (January 1955 to December 1990) of observations at MCAS New River.

Coastal plain temperatures are moderated by the proximity of the Atlantic Ocean which effectively reduces the average daily temperature fluctuation. Lying 50 miles offshore at its nearest point, the Gulf Stream has little effect on coastal temperatures. The southern reach of the cold Labrador Current offsets any warming effect the Gulf Stream might otherwise provide.

MCB, Camp Lejeune experiences hot and humid summers; however, ocean breezes frequently produce cooling effects. The winter months are mild, with occasional brief cold spells. Average daily temperatures range from 38°F to 58°F in January and 72°F to 86°F in July. The average relative humidity, between 75 and 85 percent, does not vary greatly from season to season.

Observations of sky conditions indicate yearly averages of approximately 112 clear, 105 partly cloudy, and 148 cloudy days. Measurable amounts of rainfall occur 120 days per year, on the average. Prevailing winds are generally from the south-southwest 10 months of the year. During the months of September and October, the winds blow from the north-northwest at an average speed of 6.9 miles per hour.

#### **2.1.8 Water Supply**

Potable water for MCB, Camp Lejeune is supplied entirely by groundwater. The Base does not have established groundwater preservation areas; however, because the Base controls more than 110,000 acres of land, and because much of this land has remained undeveloped, the undeveloped areas serve the function of groundwater preserves. Groundwater usage is roughly seven million gallons per day (gpd) (Cardinell, et al., 1993). Groundwater is pumped from approximately 77 of 90 water supply wells located within the boundaries of MCB, Camp Lejeune. According to Base personnel, groundwater is treated at five plants located at Hadnot Point, Holcomb Boulevard, MCAS New River, Courthouse Bay and Onslow Beach having a total capacity of 15.8 million gpd.

All of the water supply wells use the Castle Hayne aquifer. The Castle Hayne aquifer is a highly permeable, semi-confined aquifer that can yield several hundred to 1,000 gpm in municipal and industrial wells in the MCB, Camp Lejeune area. The water supply wells at the Base average 162 feet in depth; eight inches in diameter (casing); and yield 174 gpm (Harned, et al., 1989). The water is typically a hard, calcium bicarbonate type. Information concerning the supply wells was gathered from the Wellhead Management Program Engineering Study 91-36 (Geophex, 1991), the Preliminary Draft Report Wellhead Monitoring Study 92-34 (Greenhorne and O'Mara, Inc., 1992), and interviews with Base personnel. Figure 2-1 presents the Base Water Supply Wells within a one-mile radius of Site 84.

#### **2.1.9 Ecological Characteristics**

The Natural Resources and Environmental Affairs (NREA) Division of MCB, Camp Lejeune, the U.S. Fish and Wildlife Service, and the North Carolina Wildlife Resource Commission have entered into an agreement for the protection of endangered and threatened species that might inhabit MCB, Camp Lejeune. Habitats are maintained at MCB, Camp Lejeune for the preservation and protection of rare and endangered species through the Base's forest and wildlife management programs. Full protection is provided to such species, and critical habitat is designated in management plans to prevent or mitigate adverse effects of Base activities. Special emphasis is placed on habitat and sightings of alligators, osprey, bald eagles, cougars, dusky seaside sparrows, and red-cockaded woodpeckers (WAR, 1983).

Camp Lejeune covers approximately 153,000 acres, 84 percent of which is forested (USMC, 1987). Approximately 45 percent of this is pine forest, 22 percent is mixed pine/hardwood forest, and 17 percent is hardwood forest. Nine percent of the Base, a total of 3,587 acres, is wetland and includes pure pond pine stands, mixed pond pine/hardwood stands, marshes, pocosins, and wooded swamps. The Base also contains 80 miles of tidal streams, 21 miles of marine shoreline, and 12 freshwater ponds. Over half of the 153,000 acres located within the boundaries of MCB, Camp Lejeune are under forestry management. Timber producing areas are under even-aged management with the exception of those areas along streams and swamps. These areas are managed to provide both wildlife habitat and erosion control. Forest management provides wood production, increased wildlife populations, enhancement of natural beauty, soil protection, prevention of stream pollution, and protection of endangered species (WAR, 1983).

Because of the natural resources on the Base, forested areas are actively managed for timber. Game species are also managed for hunting, and ponds are maintained for fishing. Game species managed include wild turkey, white-tailed deer, black bear, grey and fox squirrels, bobwhite quail, eastern cottontail and marsh rabbits, raccoons, and wood ducks.

Aquatic ecosystems on MCB, Camp Lejeune consist of small lakes, the New River estuary, numerous tributaries, creeks, and part of the Intracoastal Waterway. A wide variety of freshwater and saltwater fish species exist here. Freshwater ponds are under management to produce optimum yields and ensure continued harvest of desirable fish species (WAR, 1983). Freshwater fish in the streams and ponds include largemouth bass, redbreast sunfish, bluegill, chain pickerel, yellow perch, and catfish. Reptiles include alligators, turtles, and snakes, including venomous species. Both recreational and commercial fishing are practiced in the waterways of the New River and its tributaries (WAR, 1983).

Many natural communities are present in the coastal plain. Subcommunities and variations of these major community types are also present and alterations of natural communities have occurred in response to disturbance and intervention (i.e., forest cleared to become pasture). The natural communities found in the Camp Lejeune area are summarized as follows:

- Loblolly Pine Forest - a dominant forest type at Camp Lejeune. Pine forest often has a dense hardwood subcanopy and shrub understory because of clear-cutting and/or fire suppression. Dense shading results in a sparse ground layer of vegetation with little probability of rare species occurring (LeBlond *et. al.*, 1994).
- Hardwood Forest - Found primarily in stream floodplains and on slopes and terraces next to stream valleys and estuarine features. Stream floodplain communities include cypress - gum swamp and coastal plain small stream swamp. Very few rare species are found in hardwood forests, but the communities themselves can be quite rare (LeBlond *et. al.*, 1994).
- Loblolly Pine/Hardwoods Community - The predominant forest type at Camp Lejeune. Second growth forest that includes loblolly pine with a mix of hardwoods - oak, hickory, sweetgum, sour gum, red maple, and holly (oak is the predominant hardwood). These forests have a low probability for rare species because of the lack of herbaceous development and overall plant diversity (LeBlond *et. al.*, 1994).
- Longleaf Pine Forest and Longleaf Pine/Hardwood Forests - Contain critical, fire maintained natural communities: Pine Savanna, Wet Pine Flatwoods, Mesic Pine Flatwoods, Pine/Scrub Oak Sanhill, and Zeric Sanhill Scrub. Some longleaf pine

forests have developed in old fields and cut-over areas. The Federal endangered red-cockaded woodpecker (Picoides Borealis) is essentially restricted to opened, burned longleaf pine forests. The pine savannas and wet pine flatwood communities are particularly important habitats for several rare species (LeBlond et. al., 1994).

- Maritime Forest - Develop on the lee side of stable sands and dunes protected from the ocean. Live oak is an indicator species with pine, cedar, yaupon, holly, and laurel oak. Deciduous hardwoods may be present where forest is mature (USMC, 1987).
- Pond Pine Forest - These forests are primarily found in pocosins and are classified by Schafale and Wealkey (1990) as the Pond Pine Woodland natural community. Red bay, sweet bay, and loblolly bay are important components of this community. These forests frequently produce areas of high plant diversity and support several rare species. The Federal endangered loosestrife (Lysimachia asperulifolia) is found in this community (LeBlond et. al., 1994).
- Freshwater Marsh - Occurs upstream from tidal marshes and downstream from non-tidal freshwater wetlands. Cattails, sedges, and rushes are present. On the coast of North Carolina, swamps are more common than marshes (USMC, 1987).
- Salt Marsh - These areas occur in saline tidal areas protected from tidal action by barrier beach features. The barrier islands fronting the Atlantic Ocean support Brackish Marsh, Upper Beach, Dune Grass, and Maritime Wet and Dry Grassland communities. Regularly flooded, tidally influenced areas dominated by salt-tolerant grasses. Saltwater cordgrass is a characteristic species. Tidal mud flats may be present during low tide. These dynamic communities are critical to such Federal endangered species as the piping plover (Charadrius Melodus) and the Federal threatened American loggerhead turtle (Caretta caretta) and the green turtle (Chelonia Mydas) (LeBlond et. al., 1994).
- Salt Shrub Thicket - High areas of salt marshes and beach areas behind dunes. Subjected to salt spray and periodic saltwater flooding. Dominated by salt resistant shrubs.
- Dunes/Beaches - Zones from the ocean shore to the maritime forest. Subjected to sand, salt, wind, and water.
- Ponds and Lakes - Low depressional areas where water table reaches the surface or where ground is impermeable. In ponds rooted plants can grow across the bottom. Fish populations managed in these ponds include redear, bluegill, largemouth bass, and channel catfish (USMC, 1987).
- Open Water - Marine and estuarine water and all underlying bottoms below the intertidal zone.

### **2.1.10 Wetlands**

The NC DENR's Division of Environmental Management (DEM) has developed guidance concerning activities that may impact wetlands (NC DENR, 1992). In addition, certain activities affecting wetlands also are regulated by the U.S. Corps of Engineers. The U.S. Fish and Wildlife Service has prepared National Wetland Inventory (NWI) maps for the Camp Lejeune, North Carolina area by stereoscopic analysis of high altitude aerial photographs (USDI, 1982).

Wetland ecosystems at MCB, Camp Lejeune can be categorized into five habitat types: (1) pond pine or pocosin; (2) sweet gum, water oak, cypress, and tupelo; (3) sweet bay, swamp black gum, and red maple; (4) tidal marshes; and, (5) coastal beaches. Pocosins provide excellent habitat for bear and deer because these areas are seldom disturbed by humans. The presence of pocosin-type habitat at MCB, Camp Lejeune is primarily responsible for the continued existence of black bear in the area. Many of the pocosins are overgrown with brush and pine species that would not be profitable to harvest (WAR, 1983).

Sweet gum, water oak, cypress, and tupelo habitat is found in the rich, moist bottomlands along streams and rivers. This habitat extends to the marine shorelines. Deer, bear, turkey, and waterfowl are commonly found in this type of habitat (WAR, 1983).

Sweet bay, swamp black gum, and red maple habitat exist in the floodplain areas of MCB, Camp Lejeune. Fauna including waterfowl, mink, otter, raccoon, deer, bear, and gray squirrel frequent this habitat (WAR, 1983).

The tidal marsh at the mouth of the New River is one of the few remaining North Carolina coastal areas relatively free from filling or other manmade changes. This habitat, which consists of marsh and aquatic plants such as algae, cattails, saltgrass, cordgrass, bulrush, and spikerush, provides wildlife with food and cover. Migratory waterfowl, alligators, raccoons, and river otter exist in this habitat (WAR, 1983).

Coastal beaches along the Intracoastal Waterway and along the outer banks of MCB, Camp Lejeune are used for recreation and to house a small military command unit. Basic assault training maneuvers are also conducted along these beaches. Training regulations presently restrict activities that would impact ecologically sensitive coastal barrier dunes. The coastal beaches provides habitat for many shorebirds (WAR, 1983).

### **2.1.11 Threatened and Endangered Species**

Certain species have been granted protection by the U.S. Fish and Wildlife Services under the Federal Endangered Species Act (16 United States Code (U.S.C.) 1531-1543), and/or by the North Carolina Wildlife Resources Commission, under the North Carolina Endangered Species Act (G.S. 113-331 to 113-337). The protected species fall into one of the following status classifications: Federal or state endangered, threatened, or candidate species; state special concern; state significantly rare; or state watch list. While only the Federal or state threatened or endangered and state special concern species are protected from certain actions, the other classified species have the potential for protection in the future.

Surveys have been conducted to identify threatened or endangered species at Camp Lejeune and several programs are underway to manage and protect them. Table 2-4 lists protected species present at the Base and their protected classifications. Of these species, the red-cockaded woodpecker, American alligator, and sea turtles are covered by specific protection programs.

The red-cockaded woodpecker is classified as state endangered. This species requires a specific habitat in mature, living longleaf or loblolly pine trees. The birds exist in family groups and young are raised cooperatively. At Camp Lejeune, 2,512 acres of habitat have been identified and marked for protection. Research on the bird at Camp Lejeune began in 1985 and information has been collected to determine home ranges, population size and composition, reproductive success, and habitat use. An annual roost survey is conducted and 36 colonies of birds have been located.

The American alligator is considered threatened in the northernmost part of its range, which includes North Carolina. The alligator is found in freshwater, estuarine, and saltwater wetlands in Camp Lejeune. Base wetlands are maintained and protected for the alligator. Signs have been erected where alligators are known to live. Annual surveys of Wallace, Southwest, French, Duck, Mill, and Stone Creeks have been conducted since 1977 to identify alligators and their habitats on Base.

Two protected sea turtles, the Atlantic loggerhead and Atlantic green turtle, nest on Onslow Beach at Camp Lejeune and are both classified as threatened species. The green turtle was found nesting in 1980; the sighting was the first time the species was observed nesting north of Georgia. The turtle returned to nest in 1985. Turtle nests on the beach are surveyed and protected, turtles are tagged, and annual turtle status reports are issued.

Four bird species (black skimmer, piping plover, Bachman's sparrow, and peregrine falcon) have also been identified during surveys at Camp Lejeune. The piping plover and peregrine falcon are classified as threatened species. The black skimmer and Bachman's sparrow are classified as special concern (state). The black skimmer and piping plover are sea and shore birds respectively. Skimmers nest on low sandy islands and sand bars along the coast and piping plovers prefer beaches with broad open sandy flats above the high tide line. Skimmers feed above open water and piping plovers feed along the edge of incoming waves. Like the black skimmer and piping plover, Bachman's sparrows are very specific in their habitat requirements. They live in open stretches of pines with grasses and scattered shrubs for ground cover. Bachman's sparrows were observed at numerous locations throughout the southern portion of Camp Lejeune.

In addition to the protected species that breed or forage at Camp Lejeune, several protected whales migrate through the coastal waters off the base during the spring and fall. These include the Atlantic right whale, finback whale, sei whale, and sperm whale. Before artillery or bombing practice is conducted in the area, aerial surveys are made to assure that whales are not present in the impact areas.

A natural heritage resources survey was conducted at Camp Lejeune (LeBlond, 1991) to identify threatened or endangered plants and areas of significant natural interest. From this survey, the rough-leaf loosestrife was the only specie identified that is both Federal and state endangered. Also, several state endangered/threatened and Federal and state candidate species were found on the Base.

#### **2.1.12 Land Use**

MCB, Camp Lejeune presently covers an area of approximately 236 square miles. Currently, the military population of MCB, Camp Lejeune is approximately 41,000 active duty personnel. The military dependent community is more than 32,000 civilian employees performing facilities management and support functions. The population of Onslow County has grown from 17,738 in 1940, before the formation of the Base, to its present population of 121,350.

During World War II, MCB, Camp Lejeune was used as a training area to prepare Marines for combat. This has been a continuing function of the facility during the Korean and Vietnam Conflicts and the recent Gulf War (i.e., Desert Storm). Toward the end of World War II, the Base was designated as home for the Second Marine Division. Since then, Fleet Marine Forces units also have been stationed here as tenant commands.

The existing land patterns in the various geographic areas within the MCB are listed, per geographic area, on Table 2-5. In addition, the number of acres comprising each land use category has been estimated and provided on the table.

## **2.2     Site 84/Building 45 Area**

This section addresses the background and setting of Site 84. In addition, a summary of previous investigations is presented.

### **2.2.1   Site Location and Setting**

Site 84 is located approximately 200 yards south of Highway 24 on the main side of MCB, Camp Lejeune, one mile west of the main gate entrance (Refer to Figure 1-1). The study area is bordered by Building 45 (an equipment and maintenance shop) to the east and south, an electrical substation to the south, Northeast Creek to the west, and railroad tracks to the north. The site area is mostly wooded and vegetated, covered by thick vegetation or grass. There is a small lagoon, possibly manmade, hidden by trees near the center of the site. The lagoon is roughly circular in shape with a diameter of approximately 50 feet. There is an access road that leads into the site from Highway 24. This access road is fenced and locked at the site boundary. The road runs through the site and terminates at Northeast Creek (refer to Figure 2-1).

The site is relatively flat with some minor surface mounds in the wooded areas. Overland surface water drainage is west in the direction of Northeast Creek.

### **2.2.2   Site History**

The site is in proximity to a former electric substation. Transformers reportedly containing polychlorinated biphenyls (PCBs) were known to be used and possibly stored at the substation. A transformer was discovered in the wooded area, east of the substation. Additional transformers (approximately 20) potentially containing PCB transformer oil were discovered and removed from the lagoon. Maintenance personnel at Building 45 have indicated that additional transformers may still be buried in areas near the lagoon; however, it was reported that public works had performed minor excavations in the area and did not discover any waste materials.

### **2.2.3   Site Geology and Hydrogeology**

In general, the subsurface geology in the vicinity of the site is characterized by unconsolidated sands, silts and/or clay. The initial foot of cover is a dark brown top soil underlain by a three foot layer of fine to medium grained brown sand. The next layer is a six to 12 foot layer of medium grained sand that ranges in color from brown to gray. Some orange and white mottling was also noted. A thin layer (approximately one to 1.5 feet thick) of coarse grained sand separates the gray to brown color zone above from a gray medium grained sand zone eight feet below. Near the bottom of the test borings made during previous investigations, the medium grained sands were described as transitioning into a gray-green color. All throughout the sand layers, varying degrees of silt and perhaps traces of clay were also present (O'Brien and Gere, 1992).

During the advancement of the borings, groundwater was encountered from four to 15 feet below ground surface (bgs). A groundwater contour map for Site 84 could not be produced for the O'Brien and Gere Investigation as no ground water monitoring wells were installed; however, groundwater flow in this area would likely flow in a north to northwesterly direction, towards Northeast Creek.

#### **2.2.4 Previous Investigations and Findings**

Presented below are summaries of previous investigations performed in the area of Site 84 and/or Building 45.

##### *UST Site Check Investigation Report, Equipment and Maintenance Shop, Building 45, UST S-941-2 (ATEC, 1992)*

This investigation was performed to investigate potential contamination in the shallow groundwater at Building 45 in the vicinity of UST S-941-2, which contained gasoline. Three shallow groundwater monitoring wells were installed and sampled. Figure 2-3 presents the locations of the monitoring wells. Results of this investigation indicated that the shallow groundwater was contaminated by petroleum-fuel related hydrocarbons. Table 2-6A presents a summary of the analytical results. Also during this investigation, the shallow groundwater was found to flow generally to the northeast, towards Highway 24, Moss Creek and Northeast Creek.

##### *Site Assessment, Tank S781, Midway Park (O'Brien and Gere, 1992)*

During the underground storage tank (UST) investigation conducted by O'Brien and Gere (1992), two soil samples, from unknown depths, were collected from the area where the transformer was discovered. Low levels of PCBs (unknown concentrations) were reported in one soil sample. Suspected PCB dielectric fluid was sampled from the discovered transformer and PCBs were reported in the sample (unknown concentrations). The contents of the transformer removed from the lagoon were not sampled. Figure 2-3 presents the locations of the sampling locations. Table 2-6B presents a summary of the analytical results.

Note that groundwater, surface water and sediment samples were not collected at the site during this investigation.

##### *Five Well Site Check and Resample One Existing Well (UST 45-1), (R.E. Wright Associates, Inc., 1994)*

This study consisted of the installation of five groundwater monitoring wells in the area of UST 45-1 (waste oil) on the south side of Building 45 (refer to Figure 2-3). One soil sample from each well boring (based on PID readings) was submitted for laboratory analysis of oil and grease, and halogenated solvents. Groundwater samples were collected from the five newly installed monitoring wells and existing well MW-16. Groundwater samples were submitted for analysis of volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs) and TCLP metals. Groundwater level measurements were collected, indicating a shallow groundwater flow to the west. The apparent reversal in groundwater flow direction between this investigation and the ATEC investigation in 1992 may be due to the broader spacing of monitoring wells installed by R.E. Wright. This spacing, as opposed to the closer spacing for the ATEC wells, would give a truer indication of area groundwater flow direction. The ATEC wells only determined flow in a small area, which may be influenced by local variations in lithology and site features. Analytical results for soils indicate contamination from oil and grease in the subsurface. Concentrations of benzene (MW-1) and naphthalene (MW-2) were the only organics detected above detection limits



in the shallow groundwater; however, these detections were below comparison standards. Table 2-6C presents the detected analytical results for soil and groundwater. Due to the highest concentrations in soil being upgradient of the UST location, conclusion was that there is an alternative/additional source of contamination.

*Leaking UST Site Assessment Report (UST S-941-2) – Building 45 (Equipment and Maintenance Shop) (Law Engineering, Inc., 1994)*

This assessment consisted of the installation of 12 soil borings, with surface and subsurface soil sampling and analysis, and the installation of seven groundwater monitoring wells and one extraction well. Additionally, ten hydropunch samples were collected from the shallow groundwater in the vicinity of the site. Figure 2-3 presents the locations of the sampling locations. As noted on Figure 2-3, locations for this investigation were generally between Building 45 and Highway 24. Table 2-6D presents a summary of the analytical results. Soil and groundwater samples were analyzed for Total Petroleum Hydrocarbons (TPH gasoline and TPH diesel) and Total Lead. No analytical data is available from this investigation on PCBs. Recommendations from this investigation included: (1) additional soil investigation to better define extent of contamination; (2) define extent of free product hydraulically downgradient from the former UST system; (3) installation of additional groundwater monitoring wells and/or collection of hydropunch samples downgradient of the former UST system to define extent of groundwater contamination; and (4) development of design plans for a free product recovery system.

*Pre-Remedial Investigation Screening Study – Sites 12, 68, 75, 76, 84, 85 and 87 (Baker Environmental, Inc., 1998)*

Surface soil, groundwater, surface water and sediment samples were obtained from Site 84 (Building 45 Area). The samples were analyzed for TCL PCBs only. Table 2-6E presents a summary of the detection of PCBs at Site 84. Figure 2-4 through 2-7 presents the results of the analytical sampling. Each of the surface soil samples and sediment samples collected from the lagoon confirmed the presence of PCB compounds. Concentrations were above the established screening standards. The risk assessment performed as part of the Pre-Remedial Investigation Screening Study did not identify a potential risk to the receptors considered. Recommendations for Site 84 included an immediate removal action for the sediments in the lagoon and the implementation of a supplemental investigation, which would focus on soil contamination.

*GW-UST 12 Report, UST Removal at Building 45 (J.A. Jones, 1999)*

J.A. Jones performed a UST removal action at Building 45 for UST S-941-2 in July 1999. UST S-941-2 was listed as a 500-gallon tank for heating oil. A total of six confirmatory samples were collected and analyzed for Total Petroleum Hydrocarbons (TPH) diesel range organics (DRO) and gasoline range organics (GRO). Results indicated levels of TPH-DRO between non-detect and 13,000 parts per million (ppm) and levels of TPH-GRO between non-detect and 5,800 ppm. Conclusions indicated that the detected petroleum hydrocarbon contamination might not be from the UST. It was suggested that the contamination might have come from other unidentified source(s), based on the long industrial operation history at Building 45. No recommendations for further action were given. Locations of the sampling points are shown on Figure 2-3 and analytical results are presented in Table 2-6F.

Concrete Chip and Surface Water Sampling, Building 45 – Former Electric Substation (Baker Environmental, Inc., 1999)

In August 1999, Baker collected five concrete chip samples and four surface water samples at the former electric substation building (Building 45). Two of the concrete chip samples were collected from the ground level floor of the building. The other three concrete chip samples were collected from walls (two samples) and a concrete pad (one sample) from the basement level of the building. It was originally proposed that sludge samples be collected from drains in the basement of the building. Upon inspection of the drains, no sludge was found. It was proposed to collect samples of ponded water from a floor drain and three subbasement floor areas. The concrete chip samples were analyzed by Toxicity Characteristic Leaching Potential (TCLP) procedures for volatiles and semivolatile organics, and metals. No volatile or semivolatile organics were detected. Concrete samples were analyzed for PCBs by TCL Method 8082. Aroclor 1260 was detected in four of the five samples, concentrations ranging from 54 to 300 µg/kg. Acetone and carbon disulfide were the only volatiles detected in water samples, but at low concentrations. Only isolated semivolatile organics were detected, except for sample BLDG 45-W-03 located in the center subbasement area. This sample exhibited 15 semivolatile constituents (primarily polynuclear aromatic hydrocarbons [PAHs]). Aroclor 1260 was detected in one water sample (BLDG 45-W-01 from the floor drain) at a concentration of 17 µg/L. A Final Trip Report (Baker, September 1999) was submitted to LANTDIV on these activities. Analytical results are presented in Table 2-6G.

#### **2.2.5 Conclusions From Previous Investigations**

Previous investigations at Site 84/Building 45 Area have been directed towards the USTs associated with Building 45 (Equipment and Maintenance Shop). These investigations have concentrated on TPH, VOC, oil and grease, and halogenated solvent contamination. O'Brien and Gere's study in 1992 detected PCBs in the subsurface soil in the area where a transformer was discovered.

Baker's Pre-RI Screening Study at Site 84 in 1998 was predicated on the discovery of transformers and the detection of PCBs in the soil. Surface soil analyses indicated PCB contamination in the area of the lagoon (where transformers were discovered) and towards Building 45. The highest concentrations of Aroclor 1260 in the surface soil were detected approximately midway between the lagoon and Building 45. Groundwater samples were collected from specific existing wells at Site 84. Analysis was initially for PCBs; however, following review of the initial analytical results, additional groundwater samples were collected from existing wells nearer to Building 45. Initial analyses for PCBs indicated no PCBs above detection limits. Additional analyses for VOCs indicated BTEX constituents and chloroform above screening standards. Surface water samples collected from the lagoon where transformers were discovered and removed did not exhibit PCB contamination, but did exhibit BTEX constituent concentrations below screening standards. Sediment samples collected from the lagoon exhibited PCB, VOC, semivolatile and diesel range organics contamination above screening standards.

Based on the results of the Pre-RI Screening Study, and results of other previous investigations, it was recommended that a Remedial Investigation/Feasibility Study (RI/FS) be conducted at Site 84/Building 45 Area to assess the extent of potential contamination. CTO-0139 (CLEAN II) has been designated for this effort.

### 3.0 DATA QUALITY AND SAMPLING OBJECTIVES

The purpose of this section is to define the site-specific RI/FS data quality and sampling objectives in order to fulfill the overall goals of characterizing the problems at Site 84, assessing potential impacts to the public health and the environment, and identifying feasible remedial alternatives for remediating the site, if necessary. The site-specific RI/FS objectives presented in this section have been identified based on the USEPA's seven-step data quality objectives process, as presented in USEPA Guidance for the Data Quality Objectives Process (USEPA, August 2000) and USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations (USEPA, January 2000).

#### 3.1 Data Quality Objectives Process

Data quality objectives (DQOs) are qualitative and quantitative statements, developed using the DQO Process, that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as a basis for establishing the quality and quantity of data needed to support the decisions. DQOs define the performance criteria that limit the probabilities of making decision errors by considering the purpose of collecting data; defining the appropriate type of data needed; and specifying tolerable probabilities of making decision errors. The seven-step DQO process is as follows:

- Step 1 – State the Problem
- Step 2 – Identify the Decision
- Step 3 – Identify the Inputs to the Decision
- Step 4 – Define the Boundaries of the Study
- Step 5 – Develop a Decision Rule
- Step 6 – Specify Tolerable Limits on Decision Errors
- Step 7 – Optimize the Design for Obtaining Data

Step 1 of the DQO Process is where the planning team is established, the problem is described and a conceptual model of the environmental hazard to be investigated is developed, and available resources, constraints and deadlines are identified.

Step 2 of the DQO Process should identify the principal study question, define alternative actions, develop a decision statement and state each decision in terms of whether to take action, and organize multiple decisions into an order of priority.

Step 3 of the DQO Process should identify the kinds of information needed, identify the sources of information, determine the basis for setting the Action Level, and confirm the appropriateness of proposed sampling and analyses.

Step 4 of the DQO Process should define the target population, determine the spatial and temporal boundaries, identify practical restraints, and define the scale of decision making.

Step 5 of the DQO Process should define the population parameter, determine what action is needed, and confirm that the Action Level exceeds minimum detection limits.

Step 6 of the DQO Process should determine the sources of error in the sample data set, establish a plausible range of values for the parameter of interest, define the two types of potential decision errors and the consequences of making those errors, determine how to manage potential decision errors, select the baseline condition of the environment that will be assumed to be true in the absence of overwhelming evidence to the contrary, specify a range of possible parameter values

where the consequences of a false acceptance decision error are considered tolerable (gray region), and assign probability values at several true value points above and below the Action Level that reflect your tolerable probability for the occurrence of decision errors.

Step 7 of the DQO Process is the review of existing environmental data, evaluation of the operational decision rules, development of general data collection design alternatives, calculation of the number of samples to be taken, and selection of the most resource-effective data collection system.

The DQO seven-step process for Site 84 is documented in the following sections.

### **3.1.1 Step 1 - State the Problem**

The first activity associated with this step was to establish the planning team. For Site 84, the planning team includes the LANTDIV Navy Technical Representative (NTR), the Activity Point of Contact (POC), EPA Region IV, NC DEHNR, and Baker's Project Manager, Project Geologist and Risk Specialist. These team members would also be decision-makers for the DQO Process. Based on existing information and data from previous investigations at the site, the problem has been described. At Site 84, polychlorinated biphenyls (PCBs) have been identified as a site contaminant requiring further investigation. Fuels have also been identified at the site from various storage tanks that have been located there; however, the nature and extent of these contaminants have been evaluated and defined during previous investigations performed under the UST program. The conceptual model for the potential environmental hazard indicates: 1) PCBs in the area of an identified lagoon; 2) old electrical transformers recovered from this area, with analysis of residual dielectric oil indicating PCBs; 3) site surface soil and sediment from the lagoon exhibited PCB concentrations, surface water and sediment samples from Northeast Creek and groundwater samples from existing site wells were also collected and analyzed for PCBs during the 1998 Pre-RI Screening Study conducted by Baker (Baker, 1998); however, no PCBs were detected in these media; and 4) the Pre-RI Screening Study identified current military personnel for evaluation for potential exposure to surface and subsurface soil via ingestion, dermal contact, and inhalation of fugitive dust. Potential field and report preparation team members have been identified based on the proposed schedule. Availability of some team members will be dependent on actual start dates for tasks. The Project Schedule is presented in Section 6.0 of the Work Plan. This schedule presents the completion and/or submittal dates for specific tasks or documents. This schedule will be adhered to as closely as possible.

### **3.1.2 Step 2 - Identify the Decision**

The principal study question identified is whether there are concentrations of PCBs in soil (i.e., surface and subsurface) above Action Levels outside of the areas that have been assessed in previous investigations, and to determine the areal extent (i.e., horizontally and vertically) of PCB contamination. Alternative actions would be to institute a removal action of known PCB contaminated soil that exceeds Action Levels with confirmatory sampling to determine extent, or take no action at all. A second question would be if the available information on groundwater were sufficient to determine/state that no PCB contamination of groundwater exists at the site.

The decision statements for the study questions would be:

“Determine the existence and areal extent of PCB contamination at Site 84 in areas identified as being contaminated with PCBs, based on previous investigations and studies. Assess the level of confidence in groundwater information/data to determine if groundwater contamination exists at the site.”

The first statement has priority, as this will determine the extent of soil contamination at Site 84 and provide information on the appropriateness and completeness on existing groundwater data to verify that groundwater contamination is not a concern at Site 84.

### **3.1.3 Step 3 - Identify the Inputs to the Decision**

Information on the extent of PCB contamination in the soil is still needed to decide on a course of action. This new information/data would be combined with existing data to determine the full extent of the PCB contamination. Sources for information include: 1) the Baker 1998 Pre-RI Screening Study; 2) Federal and State criteria and standards for soils and groundwater; 3) new data collected as part of the Remedial Investigation/Feasibility Study; and 4) Human Health and Ecological Risk Assessments. The basis for the Action Level would be determined from the Human Health and Ecological Risk Assessments as no compound specific Risk Based Concentrations (RBCs) for the particular Aroclor detected in the soils at the site are available. There are total PCB RBCs of 2.86 milligram per kilogram (mg/kg) (Industrial) and 0.319 mg/kg (Residential). These concentrations may not be appropriate for an evaluation of the PCBs detected at Site 84, so the risk assessments would be an appropriate resource for establishing Action Levels and evaluating the potential threat to human health and the environment the site PCB contamination may pose. Another resource for the Action Level is the Toxic Substance Control Act (TSCA) which lists the cleanup criteria for PCBs in low occupancy areas as 25,000 micrograms/kilogram ( $\mu\text{g/kg}$ ). Immunoassay field test kits for PCBs could be used to provide field concentrations to determine if additional locations farther from the initial investigation areas need to be sampled and evaluated. Confirmatory samples would be sent to an off site laboratory to verify the field-test results. Standard USEPA test methods for PCBs would be acceptable for determining PCB concentrations in soil in the laboratory confirmatory samples. With the new soil data on PCBs and a determination of the extent of PCB contamination, a review and evaluation of the existing groundwater monitoring well locations and analytical data would be possible. This evaluation would determine if additional monitoring wells were needed to fully characterize the shallow groundwater at Site 84. Existing Federal and State groundwater criteria and standards (i.e., Maximum Contaminant Levels [MCLs] and/or North Carolina Water Quality Standards [NCWQS]) would be applicable for the review of existing groundwater data to determine the existence of contamination in the shallow groundwater.

### **3.1.4 Step 4 - Define the Boundaries of the Study**

Based on the previous investigations, surface and subsurface soil in areas of PCB contamination has been identified as the target population. Shallow groundwater would be another target population, as far as the review and evaluation of existing data is concerned, to determine the appropriateness and completeness of the existing characterization of the groundwater. The geographical boundaries for Site 84 have been defined by MCB Camp Lejeune on the Base Master Plan. The spatial boundaries of the study area(s) have been determined from the data obtained during the Pre-RI Screening Study. This information allows the RI/FS to focus in on the specific areas that require additional investigation to define the nature and extent of the PCB contamination. There are no real temporal boundaries for the study. Sampling can be accomplished at anytime due to the relative stability of the site and contaminant of concern (e.g., PCBs are relatively immobile in the soil and tend to adhere to soil particles). The practical restraints on collection of data at Site 84 are existing buildings and site structures, Northeast Creek, site roads and Highway 24. Depending on the time of year, weather may be a practical restraint on the collection of data. The scale of the decision making is relatively small. The site itself is small with the area(s) of investigation being reasonably localized and defined. The risk assessment decision unit is also limited, as the Pre-RI identified only current military personnel exposed to site soil as the exposure scenario.

### **3.1.5 Step 5 - Develop a Decision Rule**

For the population parameter, actual chemical concentrations will be compared to the Action Level, as defined/determined by data evaluation and the risk assessments. Field detection limits for the immunoassay analyses are less than published industrial RBCs and TSCA cleanup criteria, but higher than residential RBCs. Standard detection limits for USEPA Method 8080 will be acceptable for laboratory confirmatory samples, as these limits are less than the proposed Action Level concentrations. The decision rule constructed for the RI/FS is:

“If the PCB concentrations in surface soil are greater than the designated Action Level, the upper six inches of soil will be removed. If PCB concentrations in subsurface soil are greater than designated Action Level, soil will be removed to a depth of 6 inches below the greatest depth of PCB contamination in the area or location, as defined by the field and laboratory analysis.”

The decision rule for the shallow groundwater is:

“If review of the new and existing soil data indicates that the existing groundwater monitoring wells do not provide the needed information to fully characterize the groundwater, additional monitoring wells will be installed and new and existing wells will be sampled and analyzed for PCBs.”

### **3.1.6 Step 6 - Specify Tolerable Limits on Decision Errors**

Statistical analysis of the data will not be performed. The size of the site and area(s) of contamination and existing information/data provides a strong basis for defining existing contamination. Judgmental sampling or authoritative measurements will be able to determine or set the tolerable limits of decision errors. Professional judgement in the field will be used to identify samples for confirmatory analysis. This will allow samples of various field determined concentrations to be submitted to the laboratory for confirmation, thus providing more reliable indication of the accuracy of field measurements. The use of actual sample concentrations and comparison to existing criteria or standards will limit potential errors in the study. A possible field decision error would be not collecting a sample for field analysis from an area where visual evidence suggests potential oil contamination that may contain PCBs.

### **3.1.7 Step 7 - Optimize the Design for Obtaining Data**

Existing information/data has been reviewed to evaluate and develop the data collection design alternatives for the RI/FS. The decision rule developed in Step 5 has still been shown to be valid following review of existing data. The data collection design alternatives for the RI/FS are as follows:

- Collection of both surface and subsurface soil samples for analysis.
- Use of immunoassay field testing kits for PCBs to determine extent of contamination in the identified areas.
- Confirmatory samples will be submitted to an off-site laboratory to verify field results from the immunoassay tests.
- Performance of human health and ecological risk assessments to determine potential threat to human health and the environment.

- Review of new data and an evaluation of existing data may warrant the installation of groundwater monitoring wells to verify previous groundwater sampling results and to provide new groundwater analytical data in areas deemed necessary.

## **4.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS**

This section identifies the tasks and field investigations required to complete the RI/FS activities.

### **4.1 Task 1 – Project Management**

Project Management activities involve such activities as daily technical support and guidance, budget and schedule review and tracking, preparation and review of invoices, personnel resources planning and allocation, preparation of monthly progress reports, and communications with LANTDIV and the Activity.

### **4.2 Task 2 – Subcontract Procurement**

Task 2 involves the procurement of services such as drilling, surveying, laboratory analysis and data validation. Procurement of these activities will be performed in accordance with Navy CLEAN Procurement Manual.

### **4.3 Task 3 – Field Investigations**

The field investigations will be conducted under Task 3. Following is an overview of the field investigations to be conducted at Site 84. Specific details with respect to sampling procedures, locations and number of samples, and analytical methods are provided in the Field Sampling and Analysis Plan (FSAP) and the Quality Assurance Project Plan (QAPP). The field investigations described below will provide data to meet the overall RI/FS objectives presented in Section 3.0 of this RI/FS Work Plan. Table 4-1 summarizes the sampling and analytical requirements, as well as the data quality objectives.

The following investigations and support activities will be conducted at Site 84.

#### **Surveying**

- Survey activities will include topography, site features, utilities, soil grid sampling locations and monitoring well locations.

#### **Soil Investigation**

- A surveyed grid (on 50-foot centers) will be established.
- Surface soil samples will be collected from designated locations on the grid and analyzed in the field using ENSYS field screening kits for PCBs.
- Based on results of the field screening, soil borings will be advanced in areas identified as containing PCBs in the surface soil. These soil borings will be drilled and sampled to the groundwater table to assess presence or absence of PCBs at depth.
- Soil samples from the soil borings will be analyzed in the field using the ENSYS kit for PCBs.



### Locate Drain(s)

Drains leading from former Building 45 at Site 84 to the lagoon will be located. Soil samples will be collected from beneath the pipe and analyzed using on-site methods for PCBs. The test results will be confirmed with fixed based laboratory analysis. The investigation will include:

- Excavating a trench perpendicular to the assumed location of the pipe(s) using a backhoe. Once located, the length of the pipe(s) will be followed to the lagoon to confirm type, depth, direction and number of pipes.
- Collection of approximately fifteen grab samples from beneath the pipe(s) and at any suspected “hot spots” for on-site testing.
- Documentation and photographs of the excavation.
- Backfilling the trench with existing soil.
- Completion of fixed based laboratory analysis on approximately five samples for confirmation.

### Groundwater Investigation

- A groundwater investigation will be conducted to assess the presence or absence of contamination in the surficial aquifer.

### Investigation Derived Waste Handling

- Soil cuttings generated during soil boring drilling will be backfilled and graded over.
- Soil containment in drums or roll-off boxes will be employed if contamination is visually observed or if field instrument readings indicate a potential concern.
- Liquid waste generated during the development and sampling of groundwater monitoring wells will be containerized in drums or tankers.
- One composite sample from solid (if necessary) and liquid wastes will be collected and submitted for analysis. Soil IDW samples will be analyzed for full TCLP (organics and inorganics) and RCRA hazardous waste characterization (corrosivity, reactivity and ignitability). Liquid waste IDW samples will be analyzed for full TCL organics and TAL inorganics.

Additional details regarding IDW handling and disposal is provided in the FSAP.

## **4.4 Task 4 – Sample Analysis and Validation**

This task involves efforts relating to the post-field sampling activities:

- Sample Management
- Laboratory Analysis
- Data Validation

Sample management activities involve: (1) coordination with laboratories; (2) tracking of samples submitted for analysis; (3) tracking of analyses received; and (4) tracking of information related to samples submitted and received from a third party validator. Sample management also involves resolving technical and administrative problems (e.g., reanalysis, resubmission of information).

Laboratory analysis begins when the samples are shipped from the field and received by the laboratory. Validation begins when "raw" laboratory data is received by the validator from Baker or the laboratory. Baker will receive data from the laboratory and log it into the database for tracking purposes. Alternately, the laboratory data may be sent directly from the laboratory to the validator at this same time. A validation report will be expected within three weeks following receipt of the laboratory data packages by the validator. CLP data will be validated per the CLP criteria as outlined in the following documents:

- USEPA, Hazardous Site Control Division, Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses, 1991.
- USEPA, Hazardous Site Evaluation Division, Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses, 1988.

All other data will be validated in accordance with the method of analysis using National Functional Guidelines as a reference.

#### **4.5     Task 5 – Data Evaluation**

This task involves efforts related to the data once received from the laboratory and is validated. It also involves the evaluation of any field-generated data including: water level measurements; in-situ permeability tests; test boring logs; water quality measurements; and other field notes. Efforts under this task will include the tabulation of validated data and field data, generation of test boring logs and monitoring well construction logs, generation of geologic cross-section diagrams, and the generation of other diagrams/figures/tables associated with field notes or data received from the laboratory (e.g., sampling location maps). Included in the RI report will be chain-of-custody forms and laboratory data sheets (Form 1's).

Field screening results and laboratory confirmatory sampling results will be reviewed and evaluated to verify and correlate results. Noted discrepancies will be reported and addressed, and specific conclusions/recommendations based on this evaluation will be presented in the report.

#### **4.6     Task 6 – Risk Assessment**

This section of the Work Plan will serve as the guideline for the human health baseline risk assessment (BRA) and the screening level ecological risk assessment (SERA) to be conducted at Site 84 during the RI.

Baseline human health risk assessments and SERAs evaluate the potential human health and ecological impacts that would occur in the absence of any remedial action. The risk assessments will provide the basis for determining whether or not remedial action is necessary and the justification for performing remedial actions.

The risk assessments will be performed in accordance with USEPA guidelines. The primary documents that will be utilized include:

- Risk Assessment Guidance for Superfund (RAGS): Volume I – Human Health Evaluation Manual (Part A), EPA 1989.
- RAGS: Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), EPA 1991.
- RAGS: Volume I – Human Health Evaluation Manual (Part C, Risk Evaluation of Remedial Alternatives), EPA 1991.
- RAGS: Volume I – Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments), EPA 1998.
- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, EPA 1997.
- Superfund Program Representative Sampling Guidance, Volume 3: Biological, EPA 1997.
- Supplemental Guidance to RAGS: Region IV Bulletins - Ecological Risk Assessment, EPA Region IV, 1995 (and as updated: <http://www.epa.gov/region4/waste/ots/ecolbul.htm>).
- Supplemental Guidance to RAGS: Calculating the Concentration Term, EPA 1992.
- Amended Guidance on Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders. USEPA Region IV, Memorandum 4WD-OTS, 2000.
- Supplemental Guidance to RAGS: Calculating the Concentration Term, EPA 1992.
- Exposure Factors Handbook, EPA 1999.
- Guidance for Data Usability in Risk Assessment, EPA 1990.
- Supplemental Guidance to RAGS: Region IV Bulletins - Human Health Risk Assessment, EPA Region IV, 1995 (and as updated: <http://www.epa.gov/region4/wastepgs/oftecser/otsguid.htm#hhintro>).

USEPA Region IV will be consulted for Federal guidance and the North Carolina DENR will be consulted for guidance in the State of North Carolina.

The technical components of the human health BRA and SERA are contaminant identification, exposure assessment, toxicity assessment, and risk characterization. The objectives of the risk assessment process can be accomplished by:

- Characterizing the toxicity and levels of contaminants in relevant media (e.g., soil, groundwater, surface water, sediment, air, and biota).

- Characterizing the environmental fate and transport mechanisms within specific environmental media.
- Identifying potential current and future human and/or environmental receptors.
- Identifying potential exposure routes and the extent of the actual or expected exposure.
- Defining the extent of the expected impact or threat.
- Identifying the levels of uncertainty associated with the above items.

The human health BRA and SERA will utilize all available data to date that has been properly validated in accordance with USEPA guidelines plus data that is collected and validated from additional sampling during the RI. It should be noted that the human health BRA will follow the reporting format as set forth in RAGS Part D (USEPA, 1998).

#### **4.6.1 Human Health Evaluation Process**

##### **4.6.1.1 Site Location and Characterization**

A background section will be presented at the beginning of the risk assessment to provide an overview of the characteristics of Site 84. This section will provide a site location, a general site description, and the site-specific chemicals as discussed in past reports. The physical characteristics of the site and the geographical areas of concern will be discussed. This site description will help to characterize the exposure setting.

##### **4.6.1.2 Data Summary**

Because decisions regarding data use may influence the resultant risk assessment, careful consideration must be given to the treatment of those data. For purposes of risk evaluation, the site may be partitioned into operable units, sites, and areas of concern for which chemical concentrations will be characterized and risks will be evaluated. Sites will be grouped into operable units if they are close to one another, have similar contamination, and/or may impact the same potential receptors. In selecting data to include in the risk assessment, the objective is to characterize, as accurately as possible, the distribution and concentration of chemicals in each operable unit/area of concern.

Data summary tables will be developed for each medium sampled (e.g., soil, groundwater, surface water, sediment). Each data summary table will indicate the frequency of detection, observed range of concentrations, average background concentrations (inorganics), and the means and 95 percent upper confidence limit (UCL) value of the arithmetic mean for each compound/analyte detected in each medium. In the spring of 2000, a Base Background Study was performed at MCB, Camp Lejeune. This study consisted of sampling 50 locations within the entire boundaries of the Base. Samples were collected from soil types that typify those shown on the Onslow County Soil Survey, and at relative percentages in relation to the soil types (i.e., more samples were collected from soil types that are more common in the area of MCB Camp Lejeune). Data from the RI/FS at Site 84 will be compared to the statistical values from the Base Background Study. Arithmetic means, standard deviations, and 95 percent UCLs of arithmetic means will be calculated for use in the human health BRA. In the statistical calculations, a concentration qualified as "U" (nondetect) will be incorporated as half the detection limit value given for that compound/analyte.

#### 4.6.1.3 Identifying Chemicals of Potential Concern

The primary criteria to be used in selecting the Contaminants of Potential Concern (COPCs) from the constituents detected during the sampling and analytical phase of the investigation are the USEPA Region IX Preliminary Remediation Goal (PRG) values. For naturally occurring inorganics, Region IV allows two times base-specific background to be considered as a comparison criterion when selecting COPCs (USEPA, 1995). Therefore, an analyte may be eliminated as a COPC if it is less than two times the background level. A description of the background data (including how background data was collected and comparison values were derived) will be provided in the document, *Draft Base Background Study for MCB, Camp Lejeune* (Baker, 2000), which will be referenced in the RI Report. Criteria such as historical information, prevalence, mobility, persistence, and toxicity will be considered for possible re-inclusion of a compound/analyte that was excluded as a COPC based on comparison to PRGs. Comparison to blank data will take place during the independent third party validation. The criteria chosen to establish the COPC are derived from the USEPA's RAGS (USEPA, 1989) and Region IV Supplemental Guidance to RAGS (USEPA, 1995).

All of the available sample data will undergo review upon initiation of the BRA. Common laboratory contaminants, such as acetone, methylene chloride, phthalate esters, toluene and methyl ethyl ketone, will be addressed only if concentrations are 10 times greater than the corresponding blanks. In addition, chemicals that are not common laboratory contaminants will be evaluated if they are greater than five times the laboratory blank. All validated analytical data will be reviewed to ensure that site-related compound/analyte concentrations that exceed PRG values are not eliminated based on the "10 times" and "5 times" rule discussed above. Site-related compound/analyte concentrations that exceed PRG values will be re-included as COPCs should they be eliminated based on comparison to blank data. The number of chemicals analyzed in the risk assessment will be a subset of the total number of chemicals detected at the site based on the elimination criteria discussed previously.

Tables will be prepared that list chemical concentrations for all media. Data will be further grouped according to organic and inorganic species within each table.

#### 4.6.1.4 Exposure Assessment

The objectives of the exposure assessment at MCB, Camp Lejeune will be to characterize the exposure setting, identify exposure pathways, and quantify the exposure. When characterizing the exposure setting, the potentially exposed populations will be described. The exposure pathway will identify the source, or medium, for the released chemical (e.g., groundwater), the point of potential human contact with the contaminated medium, and the exposure route(s) (e.g., ingestion). The magnitude, frequency, and duration for each exposure pathway identified will be quantified during this process.

The identification of potential exposure pathways at the site will include the activities described in the subsections that follow.

##### *Analysis of the Probable Fate and Transport of Site- Specific Chemicals*

To determine the environmental fate and transport of the chemicals of concern at the site, the physical/chemical and environmental fate properties of the chemicals will be reviewed. Some of these properties include volatility, photolysis, hydrolysis, oxidation, reduction, biodegradation, accumulation, persistence, and migration potential. This information will assist in predicting potential current and future exposures. It will help in determining those media that are currently receiving site-related chemicals or may receive site-related chemicals in the future.

The evaluation of fate and transport may be necessary where the potential for change in future chemical characteristics is likely and for those media where site-specific data on the chemical distribution is lacking. There will be a stand-alone section in the RI Report that will address fate and transport of site-related chemicals.

#### *Identification of Potentially Exposed Human Populations*

Human populations that may currently be exposed to chemicals at MCB, Camp Lejeune include base personnel and their families, base visitors, on-site workers, and/or recreational users. Nonworking residents who might be exposed to site-specific chemicals could include spouses and/or children of base personnel. Resident and nonresident workers could be exposed to chemicals as they carry out activities at any of the sites located at MCB, Camp Lejeune. The Base Master Plan will be consulted to confirm or modify these potential exposures.

It is likely that the land use at MCB, Camp Lejeune will remain the same in the future. However, in the event that land at MCB, Camp Lejeune is developed for residential use in the future, future potential human receptors are considered for evaluation. These potential human receptors include future on-site residents and future construction workers. The list of potential receptors and pathways to be evaluated will be refined during discussions with regulators prior to performing the human health BRA.

#### *Identification of Potential Exposure Scenarios Under Current and Future Land Uses*

The following exposure scenarios are not final. Exposure scenarios will be finalized after consulting with the Base Master Plan, USEPA, and the State of North Carolina when the data collected in the field has been analyzed and evaluated. Generally, current and future exposure pathways will be considered preliminarily as follows:

- Soil Pathway
  - ▶ Ingestion (current base personnel, current recreational users, current/future residents, future construction worker)
  - ▶ Dermal contact (current base personnel, current recreational users, current/future residents, future construction worker)
  - ▶ Inhalation of fugitive dust (current base personnel, current recreational users, current/future residents, future construction worker)
- Groundwater
  - ▶ Ingestion (future residents)
  - ▶ Dermal contact (future residents, future construction worker)
  - ▶ Inhalation of volatiles while showering (future residents)
- Surface Water
  - ▶ Ingestion (current base personnel, current recreational users, current/future residents)
  - ▶ Dermal contact (current base personnel, current recreational users, current/future residents, future construction worker)

- Sediment Pathway
  - Ingestion (current base personnel, current/future resident, current recreational users)
  - Dermal contact (current base personnel, current/future resident, current recreational users, future construction worker)

#### *Exposure Point Concentrations*

After the potential exposure points and potential receptors have been defined, exposure point concentrations must be calculated. The chemical concentrations at these contact points are critical in determining intake and, consequently, risk to the receptor. The data from site investigations will be used to estimate exposure point concentrations.

The exposure point concentration is an estimate of the arithmetic average concentration for a compound/analyte within an exposure unit. Ideally, the exposure point concentration should be the true average concentration within the exposure unit. However, because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent UCL of the arithmetic mean should be used as the concentration term. If it should happen that the 95 percent UCL exceeds the maximum detected value, the maximum detected value should be used as the concentration term. USEPA Region IV follows the recommendation that it is reasonable to assume that Superfund soil sampling data are lognormally distributed (USEPA, 1995). However, Region IV makes an exception to the use of the UCL as the exposure point concentration for groundwater. Groundwater exposure point concentrations should be the arithmetic average of the wells in the highly concentrated area of the plume (USEPA, 1995).

Exposure doses will be estimated for each exposure scenario from chemical concentrations at the point of contact by applying conservative default exposure assumptions promulgated by the USEPA for standard exposure scenarios that account for contact frequency, contact duration, body weight, and other route-specific factors such as breathing rate (e.g., inhalation). Whenever possible, default exposure parameters presented in the *Region IV Human Health Risk Assessment Bulletins* will be used. However, if necessary, defensible exposure parameters based on professional judgement will be developed. These factors will then be incorporated into exposure algorithms that convert the environmental concentrations into exposure doses. Intakes will be reported in milligrams of chemical taken in by the receptor (i.e., ingested, inhaled, etc.) per kilogram body weight per day (mg/kg-day). Intakes for potentially exposed populations will be calculated separately for the appropriate exposure routes and chemicals.

#### 4.6.1.5 Toxicity Assessment

Toxicity values (i.e., numerical values derived from dose-response toxicity data for individual compounds) will be used in conjunction with the intake determinations to characterize risk. Toxicity values may be taken or derived from the following sources (note that the most up-to-date toxicity information obtained from IRIS and/or HEAST will be used in the exposure assessments):

- Integrated Risk Information System (IRIS) - The principal toxicology database, which provides updated information from USEPA on cancer slope factors, reference doses, and other standards and criteria for numerous chemicals.
- Health Effects Assessment Summary Tables (HEAST) - A tabular summary of noncarcinogenic and carcinogenic information contained in IRIS.

For some chemicals, the principal references previously mentioned do not contain the required information to present toxicity values. However, such chemicals should not be excluded as COPCs because of this, and their potential health effects should be considered in the human health BRA. When a chemical has no chronic toxicity values, the value of a chemical that is related both chemically and toxicologically is used. The implications of the presence of chemicals without toxicity values and their absence from the quantitative risk assessment should be discussed in the uncertainty section.

#### 4.6.1.6 Risk Characterization

Risk characterization involves the integration of exposure doses and toxicity information to quantitatively estimate the risk of adverse health effects. Quantitative risk estimates based on the reasonable maximum exposures to the site contaminants will be calculated based on available information. For each exposure scenario, the potential risk for each chemical will be based on intakes from all appropriate exposure routes. Carcinogenic risk and noncarcinogenic hazard indices are assumed to be additive across all exposure pathways and across all of the chemicals of concern for each exposure scenario. Potential carcinogenic risks will be evaluated separately from potential noncarcinogenic effects, as discussed in the following subsections.

##### *Carcinogenic Risk*

For the potential carcinogens that are present at the site, the cancer slope factor (CSF) will be used to estimate cancer risks at low dose levels. Risk will be directly related to intake at low levels of exposure. Expressed as an equation, the model for a particular exposure route is:

$$\text{Excess lifetime cancer risk} = \text{Estimated dose} \times \text{carcinogenic slope factor}; \\ \text{or CDI} \times \text{CSF}$$

Where: CDI = Chronic Daily Intake

This equation is valid only for risk less than  $10^{-2}$  (1 in 100) because of the assumption of low dose linearity. For sites where this model estimates carcinogenic risks of  $10^{-2}$  or higher, an alternative model will be used to estimate cancer risks as shown in the following equation:

$$\text{Excess lifetime cancer risk} = 1 - \exp(-\text{CDI} \times \text{CSF})$$

Where: exp = the exponential (natural number "e")

The calculated excess lifetime cancer risk values will be compared to USEPA's target risk range of  $1 \times 10^{-6}$  to  $1 \times 10^{-4}$ , which is considered to be generally acceptable at most sites. For quantitative estimation of risk, it will be assumed that cancer risks from various exposure routes are additive. Since there are no mathematical models that adequately describe antagonism or synergism, these issues will be discussed in narrative fashion in the uncertainty analysis.

##### *Noncarcinogenic Risk*

To assess noncarcinogenic risk, estimated daily intakes will be compared with reference doses RfD for each chemical of concern. The potential hazard for individual chemicals will be presented as a hazard quotient (HQ). A hazard quotient for a particular chemical through a given exposure route is the ratio of the estimated daily intake and the applicable RfD, as shown in the following equation:



$$HQ = CDI/RfD$$

Where:      HQ = Hazard Quotient  
               CDI = Chronic Daily Intake or exposure (mg/kg-day)  
               RfD = Reference Dose (mg/kg-day)

To account for the additivity of noncarcinogenic risk following exposure to numerous chemicals through a variety of exposure routes, a hazard index (HI), which is the sum of all the hazard quotients, will be calculated. Ratios greater than one, or unity, indicate the potential for adverse effects to occur. Ratios less than one indicate that adverse effects are unlikely. This procedure assumes that the risks from exposure to multiple chemicals are additive, an assumption that is probably valid for compounds that have the same target organ or cause the same toxic effect. In some cases when the HI exceeds unity it may be appropriate to segregate effects (as expressed by the HI) by target organ since those effects would not be additive. As previously mentioned, where information is available about the antagonism or synergism of chemical mixtures, it will be appropriately discussed in the uncertainty analysis.

#### 4.6.1.7 Uncertainty Analysis

There is uncertainty associated with any risk assessment. The exposure modeling can produce very divergent results unless standardized assumptions are used and the possible variation in others are clearly understood. Similarly, toxicological assumptions, such as extrapolating from chronic animal studies to human populations, also introduce a great deal of uncertainty into the risk assessment. Uncertainty in a risk assessment may arise from many sources including:

- Environmental sampling and analysis.
- Misidentification or failure to be all-inclusive in chemical identification.
- Use of standardized input parameters or professional judgement in the exposure assessment.
- Lack of available toxicological indices and uncertainty in deriving RfDs and CSFs.
- Assumptions of additivity in the risk characterization.

The variation of any factor used in the calculation of the exposure concentration will have an impact on the total carcinogenic and noncarcinogenic risk. The uncertainty analysis will qualitatively discuss non-site and site-specific factors that may produce uncertainty in the risk assessment. These factors may include key modeling assumptions, exposure factors, assumptions inherent in the development of toxicological end points, and spatio-temporal variance in sampling.

#### 4.6.2 **Ecological Risk Assessment**

The overall purpose of an ecological risk assessment is to evaluate the likelihood that adverse ecological effects would occur or are occurring as a result of exposure to one or more physical or chemical stressors. The assessment identifies particular chemical stressors that may cause adverse effects (Chemicals of Potential Concern [COPCs]). This assessment will evaluate the potential effects of chemicals on terrestrial and aquatic receptors (e.g., flora and fauna) and their habitats, including the consideration of protected species and sensitive or critical habitats. The RI

will present a Screening Level Ecological Risk Assessment (SERA) that covers Steps 1 and 2 of the USEPA's eight step process as outlined in the Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final (USEPA, 1997a). Step 1 is Screening-level Problem Formulation and Ecological Effects Evaluation and Step 2 is Screening-level Preliminary Exposure Estimate and Risk Calculation. Step 3a, the first step of the Baseline Risk Assessment (BERA - Problem Formulation will also be presented. This step provides a more realistic evaluation of potential risks and results in a refined list of COPCs.

The SERA and Step 3a will result in a list of COPCs and recommendations regarding the need for additional assessment beyond the screening-level (unacceptable ecological risks indicated) or the removal of Site 84 from further ecological consideration (no unacceptable ecological risks indicated). The following sections describe the general technical approach that will be followed for the ecological risk assessment at Site 84.

#### 4.6.2.1 Step 1 – Screening-Level Problem Formulation and Ecological Effects Evaluation

Problem formulation concerns the development of a conceptual model for the site that addresses the environmental setting and contaminants known or suspected to exist at the site, contaminant fate and transport mechanisms, mechanisms of ecotoxicity, and categories of receptors that could be affected, the identification of complete exposure pathways, and the selection of endpoints to screen for ecological risk (USEPA, 1997a).

The environmental setting of the site will be evaluated via examination of historical information and a site visit. The Superfund Program Representative Sampling Guidance, Volume 3: Biological (USEPA, 1997b) will be used as a guide to answer the question "Is there an ecology to protect?" The site description will also address the presence or absence of threatened or endangered species and critical habitats on or in the vicinity of the site. It will include a discussion of contaminants thought to exist on the site based on historical information and available analytical data. A data summary will be presented for each ecologically relevant medium (surface soil, surface water, groundwater, sediment) including the maximum detected concentration of contaminants. Fate and transport mechanisms and mechanisms of toxicity for compound groups (e.g., pesticides, polychlorinated biphenyls [PCBs], volatile organic compounds, inorganics, etc.) will be presented to the extent that literature data are available. The conceptual model will illustrate complete exposure pathways and identify categories of ecological receptors (e.g., terrestrial and aquatic flora, fauna, and habitat) that may be affected. Finally, screening endpoints will be selected. Media-specific screening values provided by USEPA Region IV (USEPA, 1995 and 2000) will be used to screen for ecological risk.

#### 4.6.2.2 Step 2 - Screening-level Preliminary Exposure Estimate and Risk Calculation

The screening-level exposure estimate and risk calculation provides a highly conservative evaluation of potential ecological risks at a site. Although upper trophic level receptors (e.g., terrestrial mammals, and piscivorous birds) may be identified as potential receptors at the site, the screening-level assessment is limited to a comparison of analytical data to media-specific screening values. A list of COPCs is generated from all chemicals detected in one or more samples. Chemicals can be selected as a COPC for one of three reasons. In the first case, maximum detected concentrations of compounds exceed screening values. In the second case, detected concentrations are less than screening values, but analytical detection limits of non-detected samples exceed screening values. Screening Hazard Quotients (HQs) are ratios calculated by dividing the maximum detected concentration or analytical detection limit of a given compound by its screening value. In the first two cases, COPCs have Screening HQs equal

to or exceeding one. In the third case, detected compounds are retained as COPCs when there are no screening values established with which calculate Screening HQs. Compounds that are not detected in any sample are not retained as COPCs. Because of the differential toxicity of many contaminants to ecological versus human receptors, the COPCs for ecological receptors may differ from those selected for the human health risk assessment. All COPCs are carried through to Step 3.

#### 4.6.2.3 Step 3a – Refinement of the List of Chemicals of Potential Concern

In Step 3a, the list of COPCs generated in Step 2 will be further evaluated to determine which chemicals, if any, can be removed from the list based on the consideration of multiple factors that improve the realism of the risk evaluation while remaining protective of the environment. These factors may include but are not limited to those items discussed below. It is noted that in certain circumstances a chemical may be retained as a COPC (at the discretion of the risk assessor) even if one or more of the following criteria are met for the purpose of being protective of the environment.

*Refinement of exposure assumptions.* Hazard Quotients may be recalculated using the arithmetic mean of site data to provide an estimate of effects on the population level. The arithmetic mean will be calculated using one half the detection limit of non-detected samples. Screening values from Region IV may be replaced with screening criteria from other sources if appropriate. The sources and justification of their use would be documented in the text of the report. When available, site-specific data (e.g., water hardness) may be used to calculate site-specific screening values of compounds whose toxicity is affected by these parameters.

*Background data.* When available, background data from appropriately similar areas to the investigation area may be used to determine if contaminants can be considered site-related (i.e., if background concentrations are similar to or exceed site concentrations, chemicals may be removed from the COPC list).

*Chemical characteristics.* Persistence of compounds, bioaccumulation potential, and toxicity will be considered. When available, site specific data (e.g., total organic carbon levels) will be used to assess the bioavailability of compounds. Essential nutrients (calcium, potassium, magnesium, and sodium) will not be selected as COPCs due to their inherent low toxicity.

*Evaluation of risks to upper trophic level receptors.* COPCs that are likely to bioaccumulate in the food chain may be evaluated for their likelihood to adversely impact upper trophic level receptors. Bioaccumulative compounds will be defined as those compounds with lognormal octanol-water coefficients ( $\log K_{ow}$ ) of 3.0 or greater. Exposure to contaminants will be estimated via a model of uptake via the food chain under both conservative and less conservative exposure scenarios. Exposure levels will be compared to terrestrial reference values reflecting No-Observed-Adverse-Effects-Levels (NOAELs).

Receptors to be evaluated in food chain models will be selected during the site visit based upon the following criteria:

- Are known to occur, or are likely to occur, at the site
- Have a particular ecological, economic, or aesthetic value

- Are representative of taxonomic groups, life history traits, and/or trophic levels in the habitats present at the site for which complete exposure pathways are likely to exist
- Can, because of toxicological sensitivity or potential exposure magnitude, be expected to represent potentially sensitive populations at the site
- Have sufficient ecotoxicological information available on which to base an evaluation.

Based upon a preliminary evaluation of the site, the following receptors are likely be selected for an evaluation of potential ecological effects: short-tailed shrew, white-footed mouse, meadow vole, eastern screech owl, American robin, mourning dove, great blue heron, marsh wren, raccoon, and mink. It is noted that this list will be adjusted, as appropriate, following the site visit. Conservative and less conservative exposure parameters for these receptors are provided on Table 4-2 for the review and approval of risk managers. Dietary compositions of each receptor will be determined from a review of the literature and the site visit.

#### 4.6.2.4 Risk Characterization

Risk characterization integrates the results of the exposure and ecological effect analyses. The likelihood of adverse effects occurring as a result of exposure to a stressor will be evaluated.

The ecological significance of the risks characterized at the site will be discussed considering the types and magnitudes of the effects and their spatial and temporal patterns. Ecologically significant risks will be defined as those potential adverse risks or impacts to ecological integrity that affect populations, communities, and ecosystems, rather than individuals (i.e. measured impacts to individuals does not necessarily indicate impacts to the ecosystem).

#### 4.6.2.5 Uncertainty Analysis

The ecological assessment is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions that contribute to the total uncertainty in the ultimate evaluation of risk. Assumptions are made in the exposure assessment regarding potential for exposure and exposure point locations. An effort is made to use assumptions that are conservative, yet realistic. The interpretation and application of ecological effect data is probably the greatest source of uncertainty in the ecological risk assessment. The uncertainty analysis will attempt to address the factors that affect the results of the ecological risk assessment. If data gaps are identified, recommendations for addressing them will be provided.

### 4.7 Task 7 – Remedial Investigation Report

This task is intended to cover all work efforts related to the preparation of the document providing the findings once the data has been evaluated under Tasks 5 and 6. The task covers the preparation of a Draft, Draft Final and Final RI Report. This task ends when the Final RI report is submitted.

#### **4.8 Task 8 – Remedial Alternatives Screening**

This task includes the efforts necessary to select the alternatives that appear feasible and require full evaluation. The task begins during data evaluation when sufficient data are available to initiate the screening of potential technologies. For reporting and tracking purposes, the task is defined as complete when a final set of alternatives is chosen for detailed evaluation.

#### **4.9 Task 9 – Remedial Alternatives Evaluation**

This task involves the detailed analysis and comparison of alternatives using the following criteria:

- Threshold Criteria:
  - Overall Protection of Human Health and the Environment
  - Compliance with ARARs
- Primary Balancing Criteria:
  - Long-Term Effectiveness and Permanence
  - Reduction of Toxicity, Mobility and Volume Through Treatment
  - Short-Term Effectiveness
  - Implementability
  - Cost
- Modifying Criteria:
  - State and USEPA Acceptance
  - Community Acceptance

#### **4.10 Task 10 - Feasibility Study Report**

This task is comprised of reporting the findings of the Feasibility Study. This task covers the preparation of a Draft, Draft Final and Final FS report. This task ends when the Final FS report is submitted.

#### **4.11 Task 11 – Post RI/FS Support**

This task involves the technical and administrative support to LANTDIV to prepare a Draft, Draft Final and Final Responsiveness Summary, Proposed Remedial Action Plan (PRAP) and a Record of Decision (ROD). These documents will be prepared using USEPA applicable guidance documents.

#### **4.12 Task 12 – Meetings**

This task involves providing technical support to LANTDIV during the RI/FS. It is anticipated that the following meetings will be required:

- Meeting between Baker and LANTDIV/EMD to discuss the RI/FS conclusions following submission of the Draft RI/FS Report.

- A remedial project management (RPM) meeting with LANTDIV/EMD, USEPA Region IV, and the North Carolina DENR.

The meetings will be attended by the Baker Activity Coordinator, Project Manager and a Project Engineer or Risk Assessment Specialist.

## **5.0 PROJECT MANAGEMENT AND STAFFING**

The Baker Project Team will be managed by Mr. Edward J. Kleinkauf, C.P.G. The primary responsibilities of the Project Manager will be to monitor the technical performance, cost and schedule, and to maintain close communications with the Navy Technical Representative (NTR), Mr. Kirk Stevens. The Project Manager will report to Mr. Richard E. Bonelli, P.G. (Activity Coordinator). Mr. John W. Mentz, P.G. (Program Manager) will be responsible for overall quality assurance/quality control.

The Project Team will consist of a Risk Specialist, Project Engineer, Project Geologist, Health and Safety Specialist, Ecological Scientist, and technical support staff as shown in Figure 5-1.

## **6.0 SCHEDULE**

The project schedule has been prepared in accordance with the Federal Facilities Agreement (FFA), and is presented on Figure 6-1. The projected start-up of the RI/FS field investigation (July 2001) is based on finalization of the RI/FS Project Plans on or before June 1, 2001. Implementation of the RI/FS field investigation is also predicated on the allocation of additional funding for the project for the Fiscal Year 2001 (FY01).



## 7.0 REFERENCES

Camp Lejeune Federal Facility Agreement (FFA). December 6, 1989.

ATEC Associates, Inc. (ATEC). Underground Storage tank Site Check Investigation Report, Equipment and maintenance Shop, Building 45, UST S-941-2, Camp Lejeune Marine Corps Base, Jacksonville, North Carolina. ATEC Project Number: 26-17485, 1992.

Baker, 1998. Pre-Remedial Investigation Screening Study Sites 12, 68, 75, 76, 84, 85 and 87, Marine Corps Base, Camp Lejeune, North Carolina. Baker Environmental, Inc., November 1998.

Baker, 1999. Trip Report, Site 84 - Building 45 Area, Marine Corps Base, Camp Lejeune, North Carolina. Baker Environmental, Inc., September 1999.

Baker Environmental, Inc. (Baker). Draft Base Background Study for MCB, Camp Lejeune, North Carolina. Baker Environmental, Inc. November 2000.

DON, 1988. Master Plan, Camp Lejeune Complex, North Carolina. COMNAVFACENGCOM, April 8, 1988.

ESE, 1990. Site Summary Report. Final. Marine Corps Base, Camp Lejeune, North Carolina.

Halliburton/NUS, 1991. Preliminary Draft Site Inspection Report for Site 80 Paradise Point Golf Course. Marine Corps Base, Camp Lejeune, North Carolina.

Halliburton/NUS, 1991. Preliminary Draft Site Inspection Report for Site 3 Old Creosote Plant. Marine Corps Base, Camp Lejeune, North Carolina.

Halliburton/NUS, 1991. Preliminary Draft Site Inspection Report for Site 7 Tarawa Terrace Dump. Marine Corps Base, Camp Lejeune, North Carolina.

Harned, D.A., Lloyd, O.B. Jr., and Treece, M.W. Jr., 1989. Assessment of Hydrologic and Hydrogeologic Data at Camp Lejeune Marine Corps Base, North Carolina. USGS. Water Resources Investigations Report 894096.

J. A. Jones Environmental Services Company, 1999. GW-UST 12 Report, UST Removal at Building 45, Marine Corps Base, Camp Lejeune, North Carolina. 1999

Law Engineering, Inc. (Law). Leaking Underground Storage Tank Site Assessment Report, Building 45, Equipment and Maintenance Shop, UST S-941-2, Marine Corps Base, Camp Lejeune, North Carolina. 1994.

O'Brien and Gere, 1992. Site Assessment, Tank S741, Midway Park, Marine Corps Base, Camp Lejeune, North Carolina. 1992

R. E. Wright Associates, 1994. Five Well Site Check and Resample One Existing Well, Marine Corps Base, Camp Lejeune, North Carolina. 1994

Scudder, L. L. 1982. Memorandum from Environmental Law Counsel to Assistant Chief of Staff, Facilities. Office of the Staff Judge Advocate, MCB Camp Lejeune, North Carolina, October 6, 1982.

USDOA, 1984. Soil Survey, Camp Lejeune, North Carolina. U.S. Department of Agriculture. Prepared by Soil Conservation Service in Cooperation with the U.S. Marine Corps. December 1984.

USEPA, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. U. S. Environmental Protection Agency. Office of Emergency and Remedial Response, OSWER Directive 9355.301, October 1988.

USEPA, 1989a. Risk Assessment Guidance for Superfund (RAGS): Volume I – Human Health Evaluation Manual (Part A). U.S. Environmental Protection Agency. 1989.

USEPA, 1989b. Risk Assessment Guidance for Superfund (RAGS): (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessments) U.S. Environmental Protection Agency. 1989.

USEPA, 1995a. Supplemental Guidance to RAGS: Region IV Bulletins - Human Health Risk Assessment, EPA Region IV, 1995. U.S. Environmental Protection Agency, Region IV. 1995 (and as updated: <http://www.epa.gov/region4/waste/ots/ecolbul.htm>).

USEPA, 1995b. Supplemental Guidance to RAGS: Region IV Bulletins - Ecological Risk Assessment, EPA Region IV, November 1995. U. S. Environmental Protection Agency. 1995. (updated March 2000: <http://www.epa.gov/region4/waste/ots/ecolbul.htm>).

USEPA, 1997a. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (Interim Final). U. S. Environmental Protection Agency. Environmental Response Team, EPA/540/R-97-006. June 5, 1997.

USEPA, 1997b. Superfund Program Representative Sampling Guidance, Volume 3: Biological. U. S. Environmental Protection Agency. Environmental Response Team. May, 1997.

USEPA, 2000. Memorandum 4WD-OTS, Amended Guidance on Ecological Risk Assessment at Military Bases: Process Considerations, Timing of Activities, and Inclusion of Stakeholders. U. S. Environmental Protection Agency. Ted W. Simon. June 23, 2000.

Water and Air Research, Inc. (WAR). 1983. Initial Assessment Study of Marine Corps Base, Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity.

## **TABLES**

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TABLE 2-1

**GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE  
COASTAL PLAIN OF NORTH CAROLINA  
MCB, CAMP LEJEUNE, NORTH CAROLINA  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

GEOLOGIC UNITS			HYDROGEOLOGIC UNITS
System	Series	Formation	Aquifer and Confining Unit
Quaternary	Holocene/Pleistocene	Undifferentiated	Surficial Aquifer
Tertiary	Pliocene	Yorktown Formation <sup>(1)</sup>	Yorktown Confining Unit
	Miocene	Eastover Formation <sup>(1)</sup>	Yorktown Aquifer
		Pungo River Formation <sup>(1)</sup>	Pungo River Confining Unit
			Pungo River Aquifer
		Belgrade Formation <sup>(2)</sup>	Castle Hayne Confining Unit
	Oligocene	River Bend Formation	Castle Hayne Aquifer
	Eocene	Castle Hayne Formation	Beaufort Confining Unit <sup>(3)</sup>
	Palocene	Beaufort Formation	Beaufort Aquifer
	Cretaceous	Upper Cretaceous	Peedee Formation
			Peedee Aquifer
Black Creek and Middendorf Formations			Black Creek Confining Unit
			Black Creek Aquifer
Cape Fear Formation			Upper Cape Fear Confining Unit
			Upper Cape Fear Aquifer
			Lower Cape Fear Confining Unit
			Lower Cape Fear Aquifer
Lower Cretaceous <sup>(1)</sup>		Unnamed Deposits <sup>(1)</sup>	Lower Cretaceous Confining Unit
			Lower Cretaceous Aquifer <sup>(1)</sup>
Pre-Cretaceous Basement Rocks		--	

<sup>(1)</sup> Geologic and hydrologic units not present beneath Camp Lejeune.

<sup>(2)</sup> Constituents part of the surficial aquifer and Castle Hayne confining unit in the study area.

<sup>(3)</sup> Estimated to be confined to deposits of Paleocene age in the study area.

Source: Cardinell, et al., 1993

TABLE 2-2

**CLIMATIC DATA SUMMARY  
MARINE CORPS AIR STATION, NEW RIVER  
MCB, CAMP LEJEUNE, NORTH CAROLINA  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

	Precipitation (Inches)			Relative Humidity (Percent)	Temperature (Fahrenheit)			Mean Number of Days With				
								Precipitation		Temperature		
	Maximum	Minimum	Average		Maximum	Minimum	Average	>=0.01"	>=0.5"	>=90F	>=75F	<=32F
January	7.5	1.4	4.0	79	54	34	44	11	2	0	1	16
February	9.1	.9	3.9	78	57	36	47	10	3	0	2	11
March	8	.8	3.9	80	64	43	54	10	3	*	5	5
April	8.8	.5	3.1	79	73	51	62	8	2	1	13	*
May	8.4	.6	4.0	83	80	60	70	10	3	2	25	0
June	11.8	2.2	5.2	84	86	67	77	10	4	7	29	0
July	14.3	4.0	7.7	86	89	72	80	14	5	13	31	0
August	12.6	1.7	6.2	89	88	71	80	12	4	11	31	0
September	12.8	.8	4.6	89	83	66	75	9	3	4	27	0
October	8.9	.6	2.9	86	75	54	65	7	2	*	17	*
November	6.7	.6	3.2	83	67	45	56	8	2	0	7	3
December	6.6	.4	3.7	81	58	37	48	9	2	0	2	12
Annual	65.9	38.2	52.4	83	73	53	63	118	35	39	189	48

Notes:

\* = Mean no. of days less than 0.5 days

Source: Naval Oceanography Command Detachment, Asheville, North Carolina. Measurements obtained from January 1955 to December 1990.

TABLE 2-3

**HYDRAULIC PROPERTY ESTIMATES OF THE CASTLE HAYNE AQUIFER AND CONFINING UNIT  
MCB, CAMP LEJEUNE, NORTH CAROLINA  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

Hydraulic Properties	USGS Phase I Study <sup>(1)</sup>	USGS Aquifer Test <sup>(2)</sup>	ESE, Inc. <sup>(3)</sup>	NC DENR Aquifer Test <sup>(4)</sup>	RASA Estimate <sup>(5)</sup>
Aquifer transmissivity (cubic foot per day per square foot times foot of aquifer thickness)	4,300 to 24,500 average 9,500	1,140 to 1,325	820 to 1,740 average 1,280	900	10,140 to 26,000
Aquifer hydraulic conductivity (foot per day)	14 to 82 average 35	20 to 60	--	18 to 91 average 54	45 to 80 average 65
Aquifer storage coefficient (dimensionless)	--	$2.0 \times 10^{-4}$ to $2.2 \times 10^{-4}$	$5.0 \times 10^{-4}$ to $1.0 \times 10^{-3}$ average $8.0 \times 10^{-4}$	$1.9 \times 10^{-3}$	--
Confining-unit vertical hydraulic conductivity (foot per day)	--	$3.0 \times 10^{-2}$ to $4.1 \times 10^{-1}$	$1.4 \times 10^{-3}$ to $5.1 \times 10^{-2}$ average $3.5 \times 10^{-3}$	--	--

## Notes:

- (<sup>1</sup>) Analysis of specific capacity data from Harned and others (1989).  
 (<sup>2</sup>) Aquifer test at well HP-708.  
 (<sup>3</sup>) Aquifer test at Hadnot Point well HP-462 from Environmental Sciences and Engineering, Inc. (1988).  
 (<sup>4</sup>) Unpublished aquifer test data at well X24s2x, from NC DENR well records (1985).  
 (<sup>5</sup>) Transmissivities based on range of aquifer thickness and average hydraulic conductivity from Winner and Coble (1989).

Source: Cardinell, et al., 1993.

TABLE 2-4

**PROTECTED SPECIES**  
**MCB, CAMP LEJEUNE, NORTH CAROLINA**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

Species	Protected Classification
<b>Animals:</b>	
American alligator ( <i>Alligator mississippiensis</i> )	SC
Bachmans sparrow ( <i>Aimophila aestivalis</i> )	FCan, SC
Green (Atlantic) turtle ( <i>Chelonia m. mydas</i> )	T(f), T(s)
Loggerhead turtle ( <i>Caretta caretta</i> )	T(f), T(s)
Peregrine falcon ( <i>Falco peregrinus</i> )	E(f), E(s)
Piping plover ( <i>Charadrius melodus</i> )	T(f), T(s)
Red-cockaded woodpecker ( <i>Picoides borealis</i> )	E(f), E(s)
Southern Hognose Snake ( <i>Heterodon simus</i> )	FCan, SR
Diamondback Terrapin ( <i>Malaclemys terrapin</i> )	FCan, SC
Carolina Gopher Frog ( <i>Rana capito capito</i> )	FCan, SC
Cooper's Hawk ( <i>Accipiter cooperii</i> )	SC
Eastern Diamondback Rattlesnake ( <i>Crotalus adamanteus</i> )	SR
Eastern Coral Snake ( <i>Micrurus fulvius</i> )	SR
Pigmy Rattlesnake ( <i>Sistrurus miliarius</i> )	SR
Black Bear ( <i>Ursus americanus</i> )	SR
<b>Plants:</b>	
Rough-leaf loosestrife ( <i>Lysimachia asperulifolia</i> )	E(f), E(s)
Seabeach Amaranth ( <i>Amaranthus pumilus</i> )	T(f), T(s)
Chapman's Sedge ( <i>Carex chapmanii</i> )	FCan
Hirst's Witchgrass ( <i>Dichanthelium</i> sp.)	FCan
Pondspice ( <i>Litsea aestivalis</i> )	FCan
Boykin's Lobelia ( <i>Lobelia boykinii</i> )	FCan
Loose Watermilfoil ( <i>Myriophyllum laxum</i> )	FCan, T(s)
Awed Meadowbeauty ( <i>Rhexia aristosa</i> )	FCan, T(s)
Carolina Goldenrod ( <i>Solidago pulchra</i> )	FCan, E(s)
Carolina Asphodel ( <i>Tofieldia glabra</i> )	FCan
Venus Flytrap ( <i>Dionaea muscipula</i> )	FCan
Flaxleaf Gerardia ( <i>Agalinis linifolia</i> )	SR
Pinebarrens Goober Grass ( <i>Amphicarpum purshii</i> )	SR
Longleaf Three-awn ( <i>Aristida palustris</i> )	SR
Pinebarrens Sandreed ( <i>Calamovilfa brevipilis</i> )	E(s)
Warty Sedge ( <i>Carex verrucosa</i> )	SR
Smooth Sawgrass ( <i>Cladium mariscoides</i> )	SR
Leconte's Flatsedge ( <i>Cyperus lecontei</i> )	SR

TABLE 2-4 (Continued)

**PROTECTED SPECIES**  
**MCB, CAMP LEJEUNE, NORTH CAROLINA**  
**REMEIDAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

Species	Protected Classification
Erectleaf Witchgrass ( <u>Dichanthelium erectifolium</u> )	SR
Horsetail Spikerush ( <u>Eleocharis equisetoides</u> )	SR
Sand Spikerush ( <u>Eleocharis montevidensis</u> )	SR
Flaxleaf Seedbox ( <u>Ludwigia linifolia</u> )	SR
Torrey's Muhley ( <u>Muhlenbergia torreyana</u> )	E(s)
Southeastern Panic Grass ( <u>Panicum tenerum</u> )	SR
Spoonflower ( <u>Peltandra sagittifolia</u> )	SR
Shadow-witch ( <u>Ponthieva racemosa</u> )	SR
West Indies Meadowbeauty ( <u>Rhexia cubensis</u> )	SR
Pale Beakrush ( <u>Rhynchospora pallida</u> )	SR
Longbeak Baldsedge ( <u>Rhynchospora scirpoides</u> )	SR
Tracy's Beakrush ( <u>Rhynchospora tracyi</u> )	SR
Canby's Bulrush ( <u>Scirpus etuberculatus</u> )	SR
Slender Nutrush ( <u>Scleria minor</u> )	SR
Lejeune Goldenrod ( <u>Solidago</u> sp.)	SR
Dwarf Bladderwort ( <u>Utricularia olivacea</u> )	T(s)
Elliott's Yellow-eyed Grass ( <u>Xyris elliotii</u> )	SR
Carolina Dropseed ( <u>Sporobolus</u> sp.)	T(s)

## Legend:

E(f) = Federal Endangered  
 T(f) = Federal Threatened  
 Fcan = Candidate for Federal Listing  
 E(s) = State Endangered  
 T(s) = State Threatened  
 SC = State Special Concern  
 SR = State Rare

Source: LeBlond, 1994



TABLE 2-5

**LAND UTILIZATION: DEVELOPED AREAS LAND USE<sup>(1)</sup>**  
**MCB, CAMP LEJEUNE, NORTH CAROLINA**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139 (CLEAN II)**

Geographic Area	Oper.	Training (Instruc.)	Maint.	Supply/ Storage	Medical	Admin.	Family Housing	Troop Housing	CM	CO	Recreat.	Utility	Total
Iladnot Point	31 (2.9)	15 (1.4)	154 (14.3)	157 (14.4)	10 (0.9)	122 (11.3)	22 (2.0)	196 (18.1)	115 (10.7)	36 (3.3)	182 (16.9)	40 (3.7)	1,080 (100)
Paradise Point	1 (0)		3 (0.4)	1 (0)			343 (34)	19 (1.9)	31 (3.1)		610 (60.4)	2 (0.2)	1,010 (100)
Berkeley Manor/ Watkins Village							406 (80)		41 (8.1)	1 (0.2)	57 (11.2)	2 (0.5)	507 (100)
Midway Park		1 (0.4)		2 (0.7)		2 (0.7)	248 (92.2)		8 (3.0)	3 (1.1)	4 (1.5)	1 (0.4)	269 (100)
Tarawa Terrace I and II			3 (0.5)			1 (0.3)	428 (77.4)		55 (9.9)	11 (2.0)	47 (8.5)	8 (1.4)	553 (100)
Knox Trailer							57 (100)						57 (100)
French Creek	8 (1.4)	1 (0.2)	74 (12.7)	266 (45.6)	3 (0.5)	7 (1.2)		122 (20.9)	22 (3.8)	6 (1.0)	74 (12.7)		583 (100)
Courthouse Bay		73 (28.6)	28 (10.9)	14 (5.5)		12 (4.7)	12 (4.7)	43 (16.9)	15 (5.9)	4 (1.6)	43 (16.9)	11 (4.3)	255 (100)
Onslow Beach	6 (9.8)	1 (1.6)	3 (4.8)	2 (3.2)	1 (1.6)	2 (3.2)		2 (3.2)	12 (19.3)		25 (40.3)	8 (13.0)	62 (100)
Rifle Range		1 (1.3)	1 (1.3)	7 (8.8)	1 (1.3)	5 (6.3)	7 (8.8)	30 (37.5)	5 (6.3)	1 (1.3)	9 (11.3)	13 (16.3)	80 (100)
Camp Geiger	4 (1.9)	15 (6.9)	19 (8.8)	50 (23.1)		23 (10.6)		54 (25.0)	27 (12.5)	2 (1.0)	16 (7.4)	6 (2.8)	216 (100)
Montford Point	6 (2.6)	48 (20.5)	2 (0.9)	4 (1.7)	2 (0.9)	9 (3.9)		82 (35.2)	20 (8.6)	1 (0.4)	49 (21.0)	10 (4.3)	233 (100)
Base-Wide Misc.	1 (0.8)			87 (68.0)		3 (2.3)			19 (14.8)			18 (14.1)	128 (100)
<b>TOTAL</b>	<b>57 (1.1)</b>	<b>155 (3.1)</b>	<b>287 (5.7)</b>	<b>590 (11.7)</b>	<b>17 (0.38)</b>	<b>186 (3.7)</b>	<b>1,523 (30.2)</b>	<b>548 (10.8)</b>	<b>370 (7.4)</b>	<b>65 (1.3)</b>	<b>1,116 (22.2)</b>	<b>119 (2.4)</b>	<b>5,033 (100)</b>

Note:

<sup>(1)</sup> Upper number is acres, lower number is overall percent.

TABLE 2-6A

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

<i>UST Site Check Investigation Report, Building 45, UST S-941-2 (ATEC Associates, Inc., 1992)</i>			
Soil Analyses			
Sample Number	TPH (Method 8015)	BTEX	
	(mg/kg)	(µg/kg)	
MW1-S	300	Benzene	6,200
		Toluene	27,000
		Ethylbenzene	3,800
		Total Xylenes	17,000
MW2-S	2,500	Benzene	2,300
		Toluene	1,300
		Ethylbenzene	3,600
		Total Xylenes	1,900
MW3-S	<1.0	Benzene	180
		Toluene	360
		Ethylbenzene	49
		Total Xylenes	180
Groundwater Analyses			
Sample Number	TPH	BTEX	
	(mg/L)	(µg/L)	
MW1-W	6.5	Benzene	9,800
		Toluene	16,000
		Ethylbenzene	1,000
		Total Xylenes	4,700
MW2-W	0.53	Benzene	290
		Toluene	69
		Ethylbenzene	<5
		Total Xylenes	83
MW3-W	<10.0	Benzene	10
		Toluene	<5
		Ethylbenzene	<5
		Total Xylenes	22

TABLE 2-6B

**SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS**  
**SITE 84/BUILDING 45 AREA**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139**  
**MARINE CORPS BASE**  
**CAMP LEJEUNE, NORTH CAROLINA**

Site Assessment, Tank S741, Midway Park (O'Brien and Gere, 1992)		
Soil Analyses		
Sample Number	TPH (mg/kg)	
B 1 (4-6 feet)	11.1	
B 1 (9-11 feet)	6.84	
B 2 (4-6 feet)	8.12	
B 2 (11-13 feet)	9.57	
B 3 (4-6 feet)	7.89	
B 4 (4-6 feet)	12,000	
B 4 (9-11 feet)	11,000	
MW2 (9-11 feet)	18.6	
MW2 (14-16 feet)	14.6	
MW4 (9-11 feet)	15.4	
MW4 (14-16 feet)	255.0	
MW6 (9-11 feet)	14.0	
MW6 (14-16 feet)	12.6	
MW8 (0-2 feet)	6.72	
MW8 (4-6 feet)	22.8	
MW10 (4-6 feet)	16.7	
MW10 (9-11 feet)	8.38	
MW12 (4-6 feet)	7.32	
MW12 (9-11 feet)	9.11	
MW14 (0-2 feet)	4.32	
MW14 (2-4 feet)	11.4	
Groundwater Analyses (Hydropunch)		
Sample Number	Volatile Organic Compounds (µg/L)	
H5	1,3-Dichlorobenzene	6
	1,4-Dichlorobenzene	84

TABLE 2-6C

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

<i>Five Well Site Check and Resample One Existing Well (R.E. Wright Associates, Inc., 1994)</i>							
Soil Analyses							
Sample Number	Oil and Grease	Halogenated Solvents	Naphthalene	1,2,4-Trimethylbenzene	Semivolatiles	Volatiles	Inorganics
MW-1 (4-6')	1,200	BDL	BDL	BDL	BDL	BDL	BDL
MW-2 (4-6')	2,400	BDL	0.008	0.010	BDL	BDL	BDL
MW-3 (6-8')	4,700	BDL	BDL	BDL	BDL	BDL	BDL
MW-3 (Duplicate)	2,300	BDL	BDL	BDL	NA	NA	NA
MW-4 (6-8')	420	BDL	BDL	BDL	BDL	BDL	BDL
MW-5 (6-8')	2,400	BDL	BDL	BDL	BDL	BDL	BDL
MW-5 Duplicate	1,300	BDL	BDL	BDL	NA	NA	NA
Groundwater Analyses							
Sample Number	Total VOCs	Benzene	Total PAHs	Naphthalene	RCRA Metals		
MW-1	BDL	5.4	BDL	BDL	BDL		
MW-2	BDL	BDL	BDL	8	BDL		
MW-2 (Duplicate)	BDL	BDL	BDL	10	BDL		
MW-3	BDL	BDL	BDL	BDL	BDL		
MW-3 (Duplicate)	BDL	BDL	BDL	BDL	BDL		
MW-4	BDL	BDL	BDL	BDL	BDL		
MW-5	BDL	BDL	BDL	BDL	BDL		
MW-16	BDL	BDL	BDL	BDL	BDL		

TABLE 2-6D

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

<i>Leaking UST Site Assessment Report, Building 45, UST S-941-2 (Law Engineering, Inc., 1994)</i>							
Soil Analyses							
Sample Location	Sample ID Number	Sample Depth (feet)	Laboratory Results				
			TPH-GRO (mg/kg)	TPH-DRO (mg/kg)	Total Lead (mg/kg)	TCLP Lead (µg/L)	pH
MW-4	S-1	3.0 - 4.5	ND	ND	8.3	47	4.9
MW-4	S-2	8.5 - 10.0	ND	ND	NA	NA	NA
MW-5	S-3	3.5 - 4.0	ND	ND	ND	NA	NA
MW-5	S-4	8.5 - 10.0	ND	ND	NA	NA	NA
MW-7	S-5	1.5 - 3.0	ND	ND	7.5	40	6.5
MW-8	S-6	3.0 - 4.5	ND	ND	NA	NA	NA
MW-10	S-7	1.5 - 3.0	ND	ND	9.9	NA	NA
PW-1	S-8	1.5 - 3.0	ND	ND	8.5	70	5.6
SB-1	S-9	1.5 - 3.0	ND	ND	9.7	NA	7.0
SB-2	S-10	1.5 - 3.0	ND	ND	NA	NA	NA
SB-3	S-11	3.0 - 4.5	700	190	6.2	NA	6.8
SB-4	S-12	3.0 - 4.5	ND	ND	ND	NA	7.4
Groundwater Analyses							
Well #	Screened Interval (ft.)	Laboratory Analyses <sup>(1)</sup>					
		Benzene	Ethylbenzene	Toluene	Total Xylenes	MTBE	Lead
MW-4	6 - 21	ND	ND	ND	ND	ND	59
MW-5	4.5 - 19.5	ND	ND	ND	ND	ND	---
MW-6	45 - 50	ND	ND	ND	ND	ND	---
MW-7	3 - 23	ND	ND	ND	ND	ND	84
MW-8	4 - 19	ND	ND	ND	ND	ND	20

TABLE 2-6D (continued)

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

Groundwater Analyses							
Well #	Screened Interval (ft.)	Laboratory Analyses <sup>(1)</sup>					
		Benzene	Ethylbenzene	Toluene	Total Xylenes	MTBE	Lead
MW-10	3 – 18	ND	1.6	ND	1.6	ND	---
PW-1	3 – 23	87	70	700	1900	ND	---
HP-1	8.5 – 10.0	ND	ND	ND	ND	ND	54
HP-2	NSC	NA	NA	NA	NA	NA	NA
HP-3	16.0 – 19.0	ND	ND	1.3	ND	5.4	30
HP-4	25.5 – 27.0	64	3.2	83	17	ND	48
HP-5	8.5 – 10.0	ND	ND	0.7	ND	ND	---
HP-6	8.5 – 10.0	ND	ND	ND	ND	ND	8.0
HP-7	8.5 – 12.0	ND	ND	0.8	ND	ND	42
HP-8	8.5 – 10.0	ND	ND	0.6	ND	ND	---
HP-9	22.0 – 23.5	1.0	ND	1.3	ND	ND	---
HP-10	28.2 – 29.7	ND	ND	0.8	ND	ND	---

## Notes:

- (1) All results are µg/L  
 MW Monitoring Well Location  
 SB Soil Boring Location  
 PW Pumping Well Location  
 HP Hydropunch Location  
 ND Not Detected  
 NA Not available  
 --- Sample not analyzed for this parameter  
 MTBE Methyl tert-butyl ether

TABLE 2-6E

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

<i>Pre-RI Screening Study (Baker Environmental, Inc., 1998)</i>								
Media	Fraction	Detected Contaminants or Analytes	Comparison Criteria	Min.	Max.	Location of Maximum Detection	Detection Frequency	Detections Above Screening Standard
Surface Soil (0-6")	PCBs	Aroclor-1260	320 / 1,000 <sup>(1)</sup>	110J	26,000	84-SB27	19/24 - 7/24	19/24
Surface Soil (6-12")	PCBs	Aroclor-1260	320 / 1,000 <sup>(1)</sup>	62J	200,000	84-SB27	18/24 - 11/24	18/24
Groundwater	Volatiles	Chloroform	0.19 / NE <sup>(2)</sup>	16	16	AST781-GW11-98B AST781-GW12-98B	2/7 - NE	2/7
		Benzene	1.0 / 5.0 <sup>(2)</sup>	1.5J	3.4J	AST781-GW03-98B	3/7 - 0/7	3/7
		Ethylbenzene	29 / 700 <sup>(2)</sup>	3.6J	6.7J	AST781-GW04-98B	3/7 - 0/7	0/7
	PCBs	ND	NA	ND	ND	ND	0/7	NA
Surface Water	Volatiles	Acetone	NE	5.6J	5.6J	84-SW07	1/1	NA
		Benzene	53 <sup>(3)</sup>	1.2J	1.2J	84-SW07	1/1	0/1
		Toulene	175 <sup>(3)</sup>	2.7J	2.7J	84-SW07	1/1	0/1
		Xylenes (total)	NE	3.5J	3.5J	84-SW07	1/1	NA
	Semivolatiles	ND	NA	ND	ND	ND	0/1	NA
	PCBs	ND	NA	ND	ND	ND	0/1	NA
Sediment	Volatiles	Xylenes (total)	NE	910J	910J	84-SD07	1/1	NA
	Semivolatiles	Naphthalene	160 <sup>(4)</sup>	2,000	2,000	84-SD07	1/1	1/1
		Phenanthrene	240 <sup>(4)</sup>	2,500	2,500	84-SD07	1/1	1/1
		Bis(2-Ethylhexyl)phthalate	NE	2,400J	2,400J	84-SD07	1/1	NA
	Diesel Range Organics	TOTAL	NE	3500	14000	84-SD01	NA	NA
		2-Methylnapthalene	70 <sup>(4)</sup>	10,000	10,000	84-SD07	1/1	1/1
	PCBs	Aroclor-1248	22.7 <sup>(4)(5)</sup>	2,800	2,800	84-SD05	1/11	1/11
		Aroclor-1260	22.7 <sup>(4)(5)</sup>	3,700	49,000	84-SD01	8/11	8/11

Notes: - Concentration are presented in  $\mu\text{g/kg}$  for solids (ppb).

NA - Not applicable

NE - Not established

ND - Not detected

<sup>(1)</sup> USEPA Region III Residential RBCs/TSCA (Toxic Substances Control Act) Clean-up Criteria

<sup>(2)</sup> NC WQC (North Carolina Water Quality Criteria) for groundwater / USEPA Maximum Contaminant Level

<sup>(3)</sup> Supplemental Guidance to RAGS: Region 4 Bulletins Ecological Risk Assessment

<sup>(4)</sup> Long, et. al., 1995

<sup>(5)</sup> Value for Total PCBs

TABLE 2-6F

**SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS**  
**SITE 84/BUILDING 45 AREA**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139**  
**MARINE CORPS BASE**  
**CAMP LEJEUNE, NORTH CAROLINA**

<i>GW-UST 12 Report, UST Removal at Building 45 (J.A. Jones, Inc., 1999)</i>						
Soil Analyses						
Sample ID	Date	Depth (ft)	FID (ppm)	PID (ppm)	TPH-DRO (ppm)	TPH-GRO (ppm)
Bldg. 45	7/22/99	6" below UST	2.0	0.0	220	BDL
45 - 1	8/5/99	8" below UST	--	--	BDL	BDL
45 - 2	8/5/99	9" below UST	--	--	100	3.9
45 - 3	8/5/99	12" below UST	--	--	37	BDL
45 - 4	8/5/99	15" below UST	--	--	110	2.5
45 - 5	8/5/99	12" below UST	--	--	13,000	5,800



TABLE 2-6G

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

<i>Trip Report, Site 85 – Building 45 Area (Baker Environmental, Inc., 1999)</i>						
Concrete Analyses						
Sample ID	Date	TCLP VOCs (mg/L)	TCLP SVOCs (mg/L)	TCLP Metals (mg/L)	TCLP Mercury (mg/L)	PCBs (µg/kg)
BLDG 45-C-01	8/19/99	ND	ND	ND	ND	AR 1260 (160)
BLDG 45-C-02	8/19/99	ND	ND	ND	ND	AR 1260 (300)
BLDG 45-C-03	8/19/99	ND	ND	CR (0.23)	ND	AR 1260 (220)
BLDG 45-C-04	8/19/99	ND	ND	ND	ND	ND
BLDG 45-C-05	8/19/99	ND	ND	ND	ND	AR 1260 (54)

Aqueous Analyses				
	BLDG 45-W-01	BLDG 45-W-02	BLDG 45-W-03	BLDG 45-W-04
<i>Volatiles (µg/L):</i>				
Acetone	ND	ND	43	ND
Carbon Disulfide	1.5	3.5	ND	ND
<i>Semivolatiles (µg/L):</i>				
Acenaphthene	ND	ND	68	27
Dibenzofuran	ND	ND	50	23
2,4-Dinitrotoluene	ND	ND	ND	17
Fluorene	ND	ND	70	27
Phenanthrene	ND	22	390	130
Anthracene	ND	ND	100	38
Fluoranthene	ND	26	480	140
Pyrene	ND	15	250	91
Benzo(a)anthracene	ND	ND	180	59
Bis(2-Ethylhexyl)phthalate	ND	ND	ND	10
Chrysene	ND	11	200	66
Benzo(b)fluoranthene	ND	ND	140	49
Benzo(k)fluoranthene	ND	ND	180	58
Benzo(a)pyrene	ND	ND	150	50

TABLE 2-6G

SUMMARY OF PREVIOUS INVESTIGATIONS RESULTS  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-139  
 MARINE CORPS BASE  
 CAMP LEJEUNE, NORTH CAROLINA

Aqueous Analyses				
	BLDG 45-W-01	BLDG 45-W-02	BLDG 45-W-03	BLDG 45-W-04
Indeno(1,2,3-cd)pyrene	ND	ND	75	22
Benzo(g,h,i)perylene	ND	ND	71	17
Carbazole	ND	ND	180	73
PCBs ( $\mu\text{g/L}$ ):				
Aroclor 1260	17	ND	ND	ND
Metals ( $\text{mg/L}$ ):	Various	Various	Various	Various

NOTES:

ND – non-detect

TABLE 3-1

**SITE 84/BUILDING 45 AREA**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY OBJECTIVES, CTO-0139**  
**MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Medium or Area of Concern	RI/FS Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Site 84 - Soil	1a. Assess the extent of soil contamination in the Site 84/Building 45 Area.	Characterize contaminant levels in surface and subsurface soils.	Soil Investigation
	1b. Assess human health and ecological risks associated with exposure to surface soils at the site.	Characterize contaminant levels in surface soils at the study area.	Soil Investigation Risk Assessment
	1c. Determine whether contamination from soils is migrating to groundwater.	Characterize subsurface soil and leaching potential. Characterize shallow groundwater.	Soil Investigation Groundwater Investigation
	1d. Evaluate treatment alternatives.	Characterize areas of concern above action levels. Evaluate effectiveness and implementability of technologies.	Soil Investigation Feasibility Study Bench or Pilot-Scale Testing
2. Site 84 - Groundwater	2a. Assess nature and extent of shallow groundwater contamination.	Characterize shallow groundwater quality.	Groundwater Investigation
	2b. Define hydrogeologic characteristics for fate and transport evaluation and remedial technology evaluation, if required.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, transmissivity, permeability, etc.).	Groundwater Investigation
	2c. Assess health risks posed by potential future usage of the shallow groundwater.	Evaluate groundwater quality and compare to groundwater criteria and risk-based action levels.	Groundwater Investigation Risk Assessment

TABLE 4-1

**SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES  
SITE 84/BUILDING 45 AREA  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Study Area	Investigation	Baseline No. of Samples <sup>(1)</sup>	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 84/ Building 45 Area	Surface Soil Sampling	96 locations	ENSYS for PCBs TCL PCBs	II III	ENSYS CLP/SOW	Routine <sup>(4)</sup>
	Soil - Well Borings	6 borings/2 samples per boring	ENSYS PCBs TCL PCBs	II III	ENSYS CLP/SOW	Routine Routine
	Groundwater - Two rounds sampling	6 new shallow monitoring wells 4 existing shallow monitoring wells	TCL PCBs	III III	CLP/SOW CLP/SOW	Routine Routine
	IDW - Soil	2	TCLP <sup>(5)</sup> RCRA <sup>(6)</sup>	III	SW846	Routine
	IDW - Water	2	TCL Organics <sup>(2)</sup> TAL Metals <sup>(3)</sup> (total/dissolved)	III	CLP/SOW CLP/SOW	Routine Routine

## Notes:

<sup>(1)</sup> Baseline number of samples do not include QA/QC samples.

<sup>(2)</sup> TCL Organics: volatile organics, semivolatile organics, pesticides/PCBs

<sup>(3)</sup> TAL Metals:

Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

<sup>(4)</sup> Routine analytical turnaround is 28 days following receipt of samples.

<sup>(5)</sup> TCLP - TCL VOAs, TCL SVOAs, TCL Pesticides, Herbicides, and Metals

<sup>(6)</sup> RCRA - Corrosivity, Reactivity, and Ignitability (React Sulfide, React Cyanide)

## **FIGURES**

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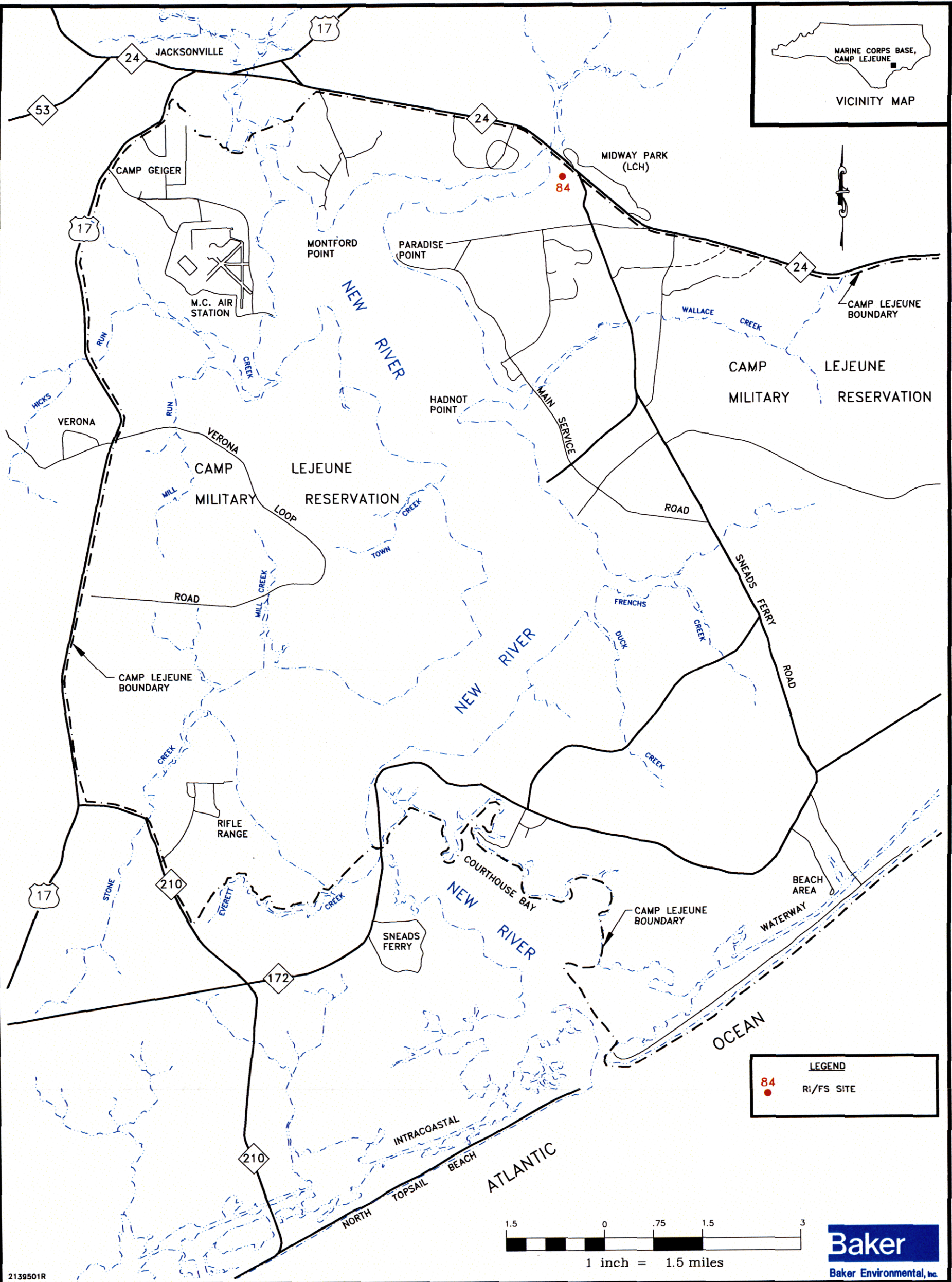


FIGURE 1-1  
SITE LOCATION MAP  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139 (CLEAN II)

MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA

**Baker**  
Baker Environmental, Inc.









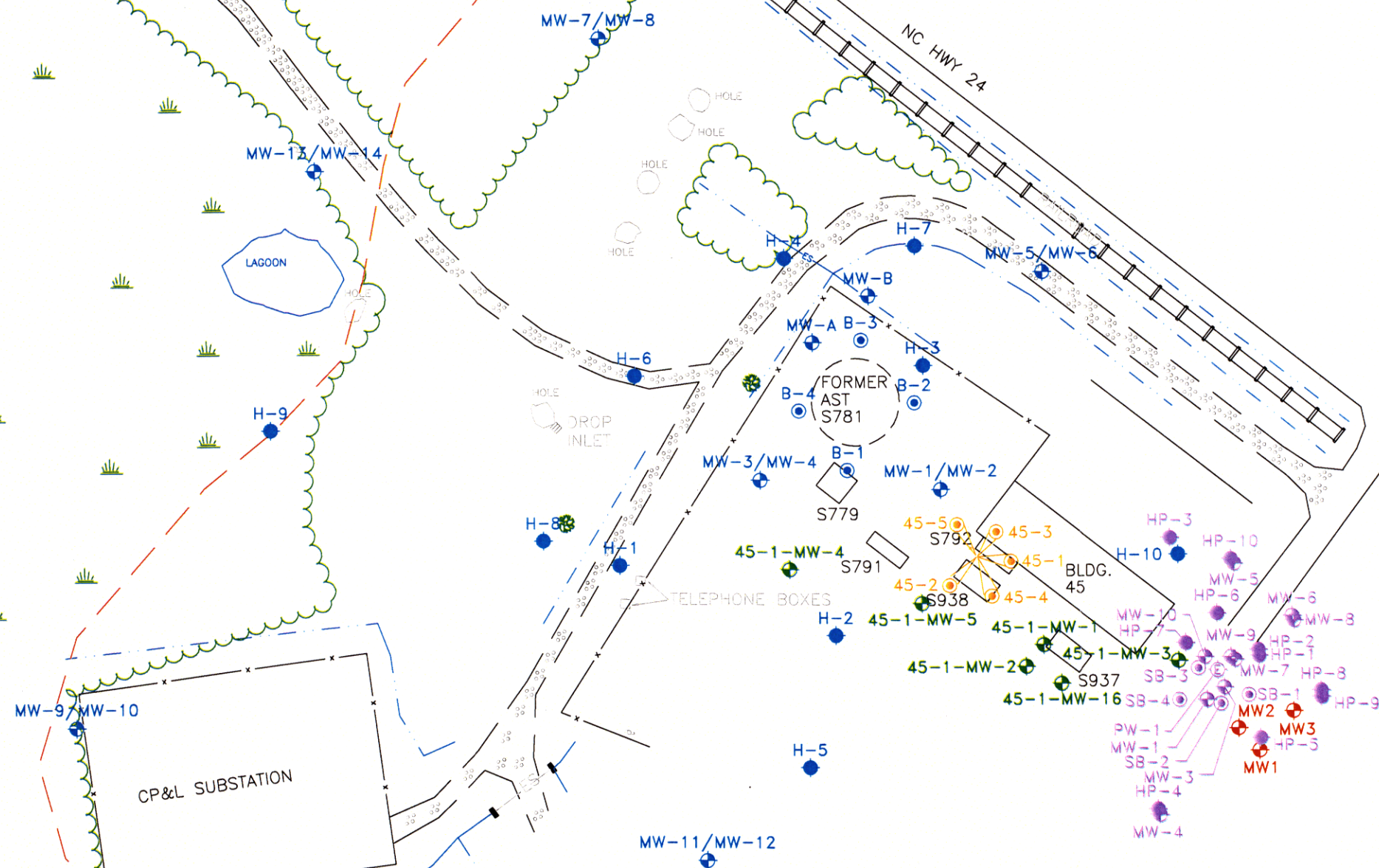
- INTERMITTENT DRAINAGE SWELL
- TREE LINE
- GRAVEL ROAD

SOURCE: BRENT A. LANIER R.L.S., JANUARY 1996.

FIGURE 2-2  
SITE MAP  
SITE 84  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA



NORTHEAST CREEK  
EDGE OF BANK



NOTE: 1.) UNDERGROUND WIRES, LINES, PIPES AND OTHER UTILITIES WERE NOT ATTEMPTED TO BE SURVEYED AT THIS TIME.  
2.) WETLAND BOUNDARY IS BASED ON NATIONAL WETLANDS INVENTORY MAPS.

LEGEND	
	- INTERMITTENT DRAINAGE SWALE
	- TREE LINE
	- GRAVEL ROAD
	- WETLAND
	- APPROXIMATE WETLAND BOUNDARY
	- EXTRACTION WELL LOCATION
	- HYDROPUNCH LOCATION
	- MONITORING WELL LOCATION
	- SOIL BORING LOCATION
	- ATEC SAMPLE
	- O'BRIEN AND GERE SAMPLE
	- R.E. WRIGHT SAMPLE
	- LAW ENGINEERING SAMPLE
	- J.A. JONES SAMPLE

SOURCE: BRENT A. LANIER R.L.S., JANUARY 1996.

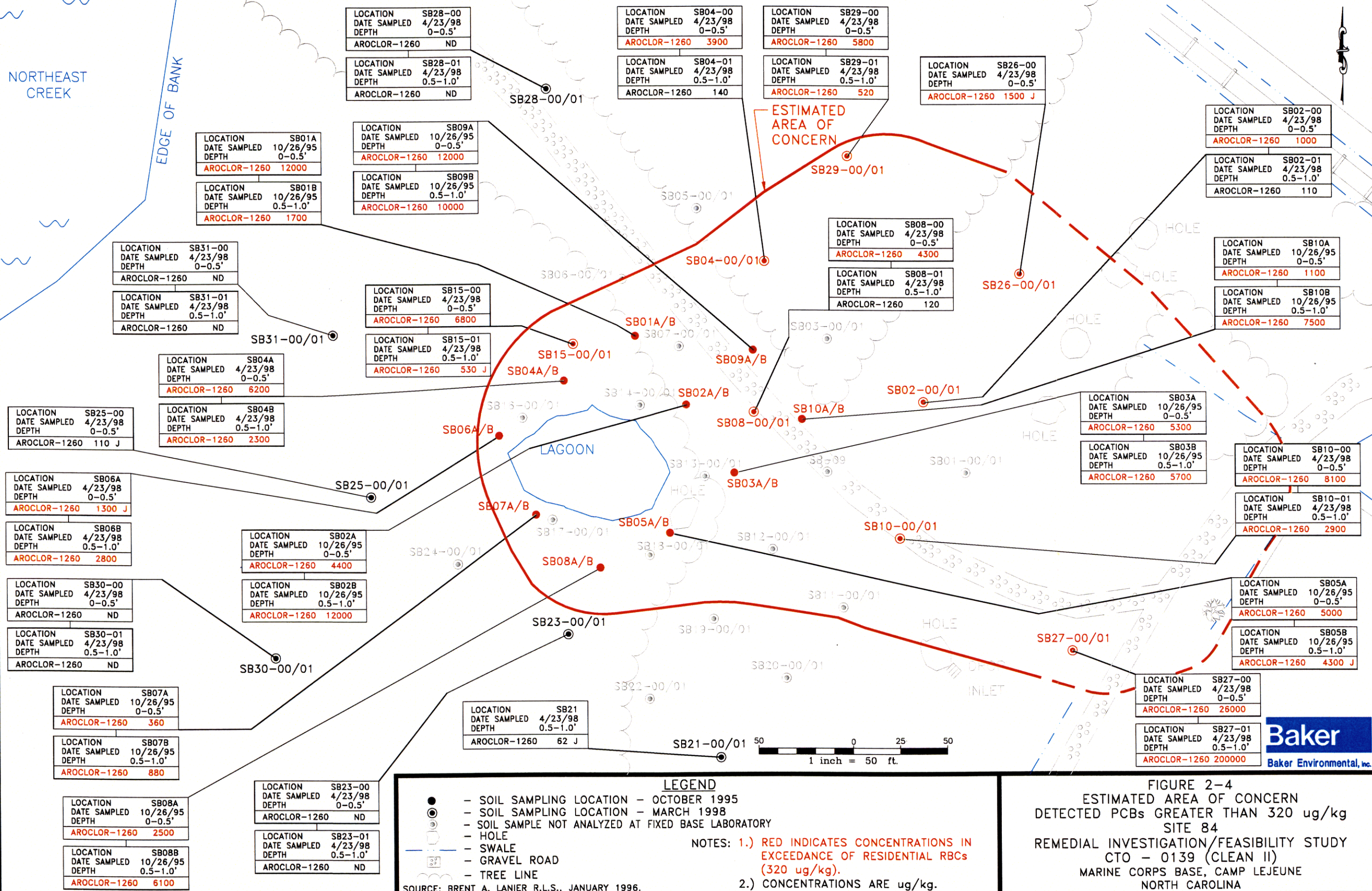
FIGURE 2-3  
PREVIOUS INVESTIGATIONS SAMPLE LOCATION MAP  
SITE 84  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139  
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA

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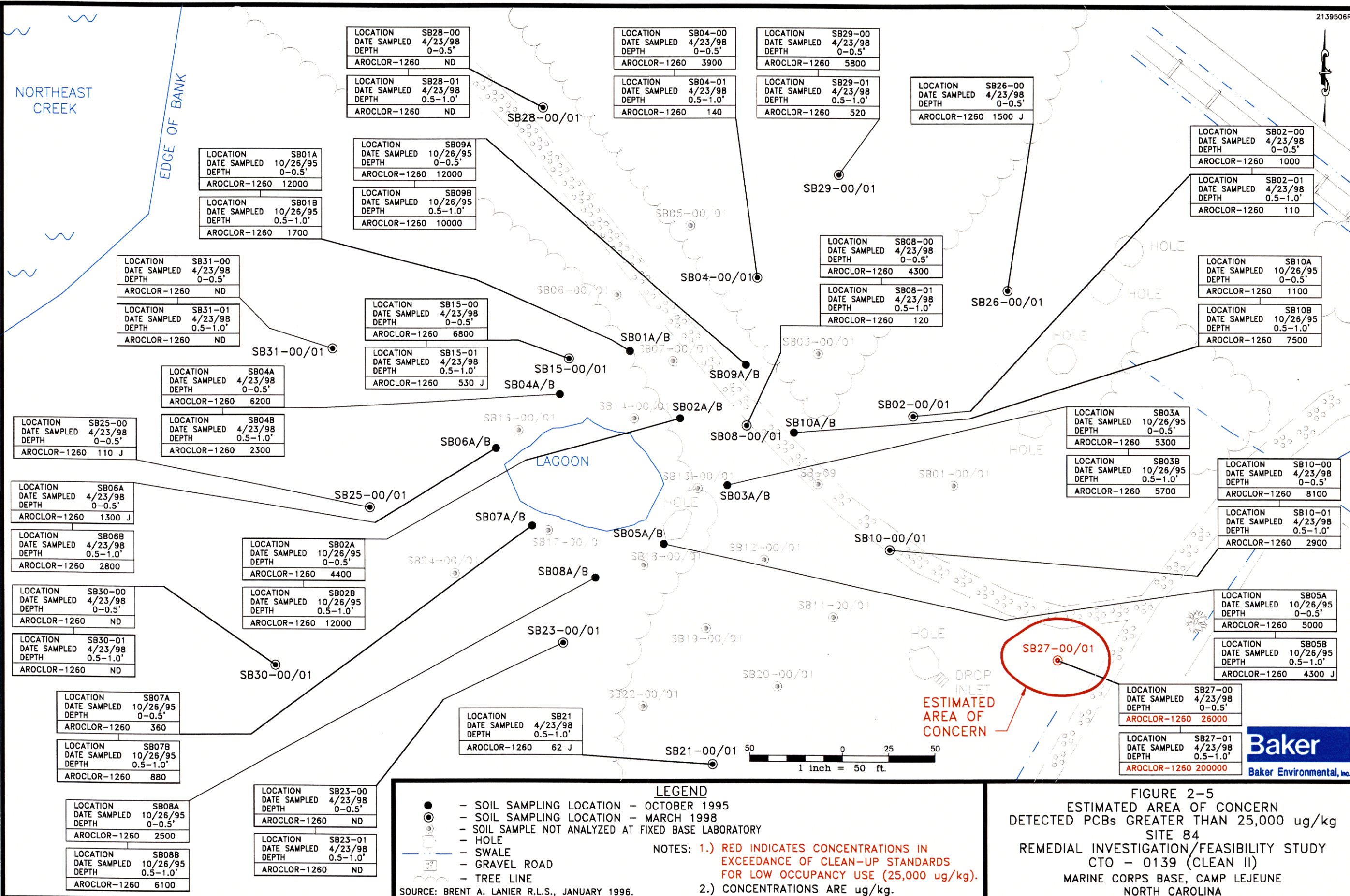


NORTHEAST  
CREEK

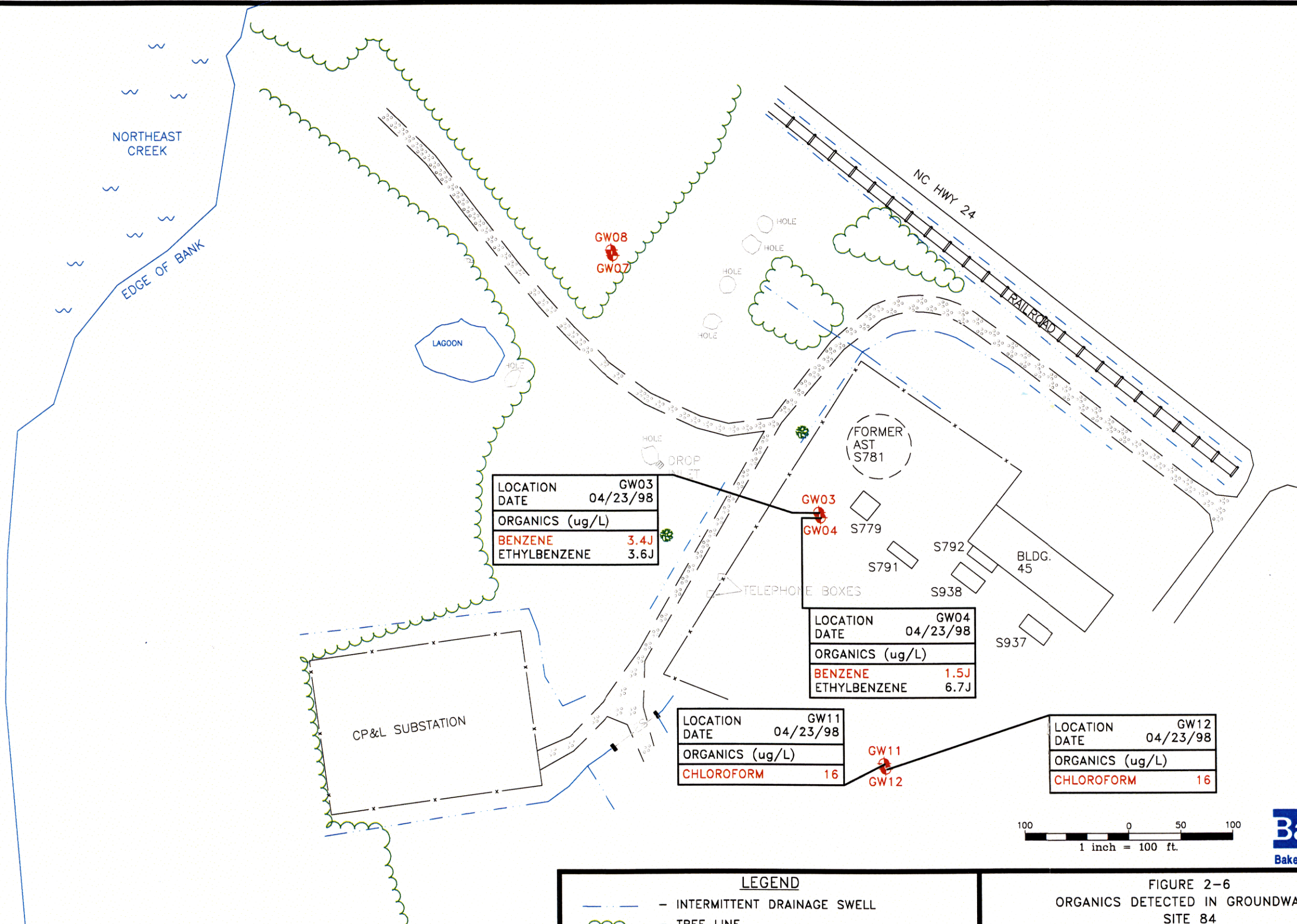
EDGE OF BANK











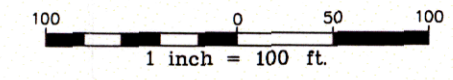
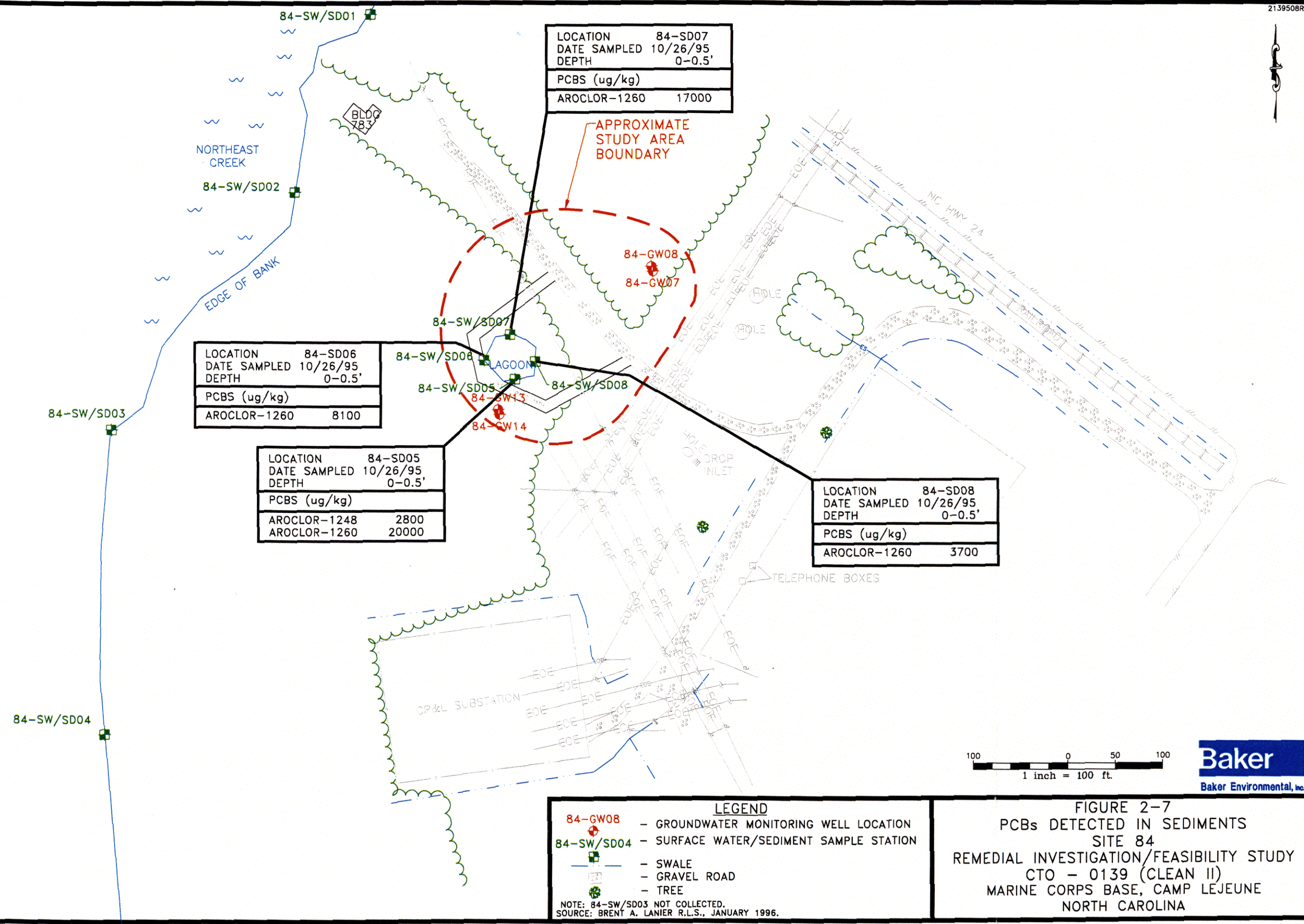
NOTE: UNDERGROUND WIRES, LINES, PIPES AND OTHER UTILITIES WERE NOT ATTEMPTED TO BE SURVEYED AT THIS TIME.

100 0 50 100  
1 inch = 100 ft.

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FIGURE 2-6  
ORGANICS DETECTED IN GROUNDWATER  
SITE 84  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA





**FIGURE 2-7**  
**PCBs DETECTED IN SEDIMENTS**  
**SITE 84**  
**REMEDIAL INVESTIGATION/FEASIBILITY STUDY**  
**CTO - 0139 (CLEAN II)**  
**MARINE CORPS BASE, CAMP LEJEUNE**  
**NORTH CAROLINA**

**FIGURE 5-1**  
**PROJECT ORGANIZATION**

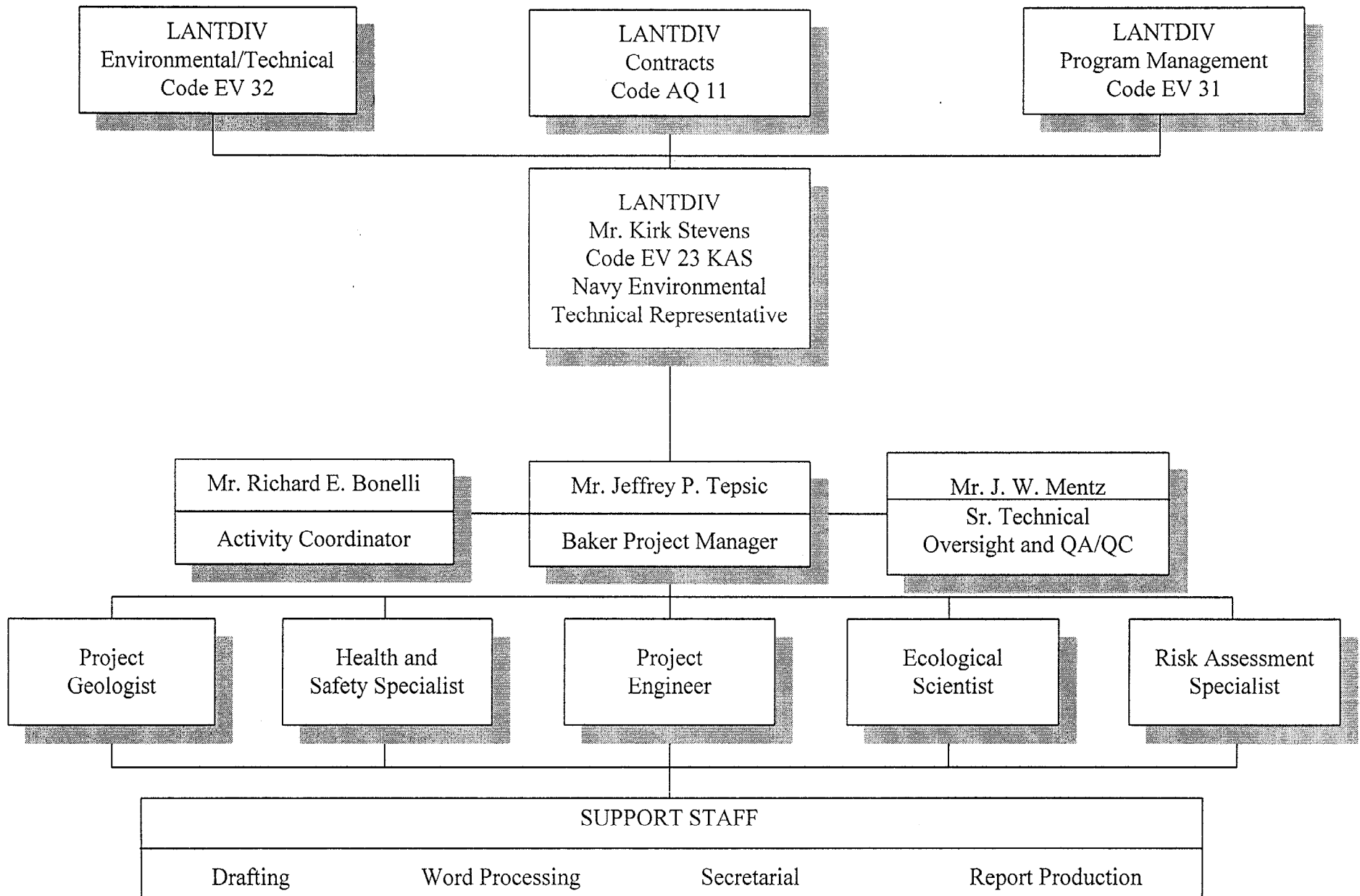


Figure 6-1 - Project Schedule  
Site 84/Building 45 Area  
MCB Camp Lejeune, NC

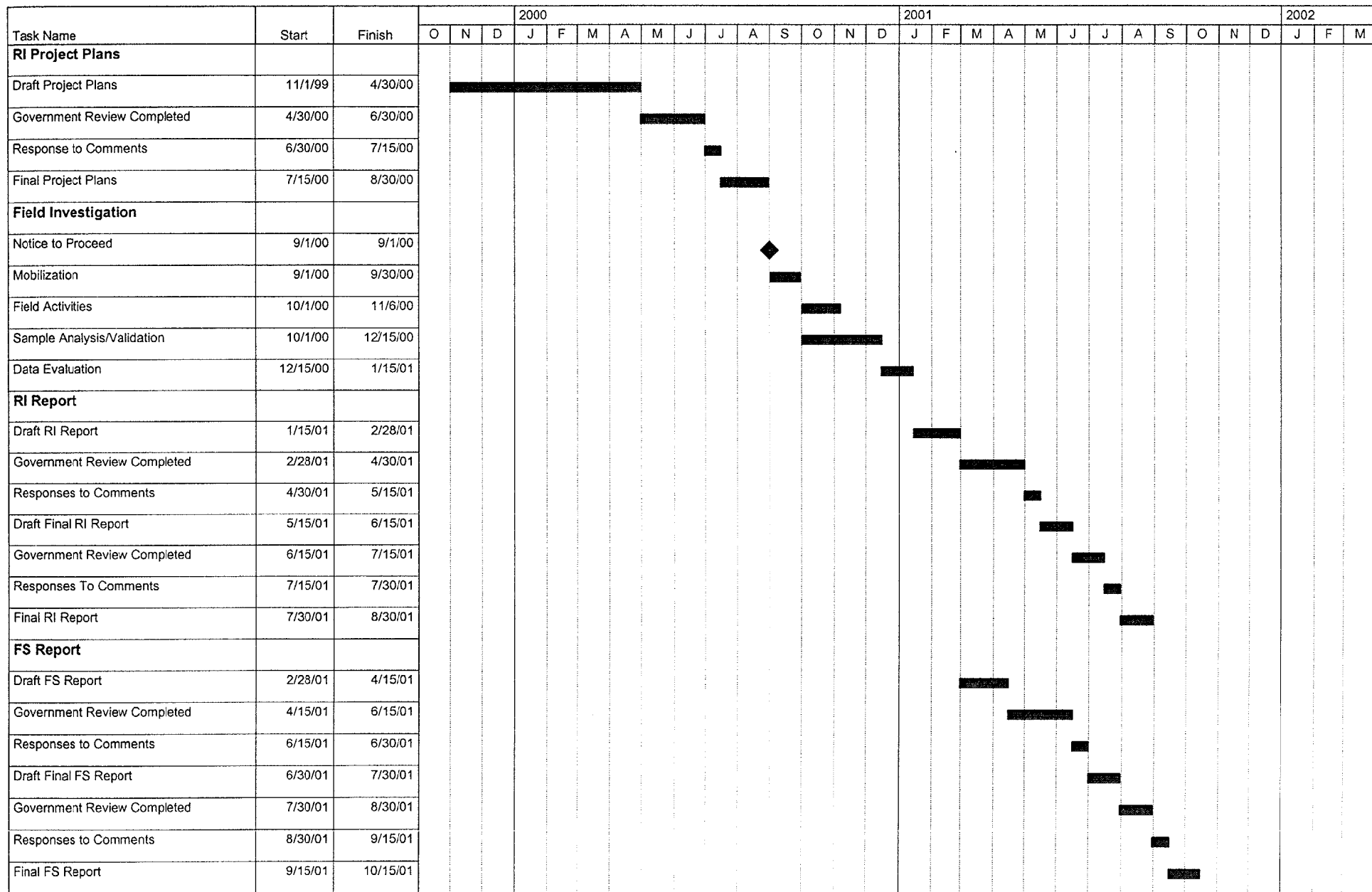
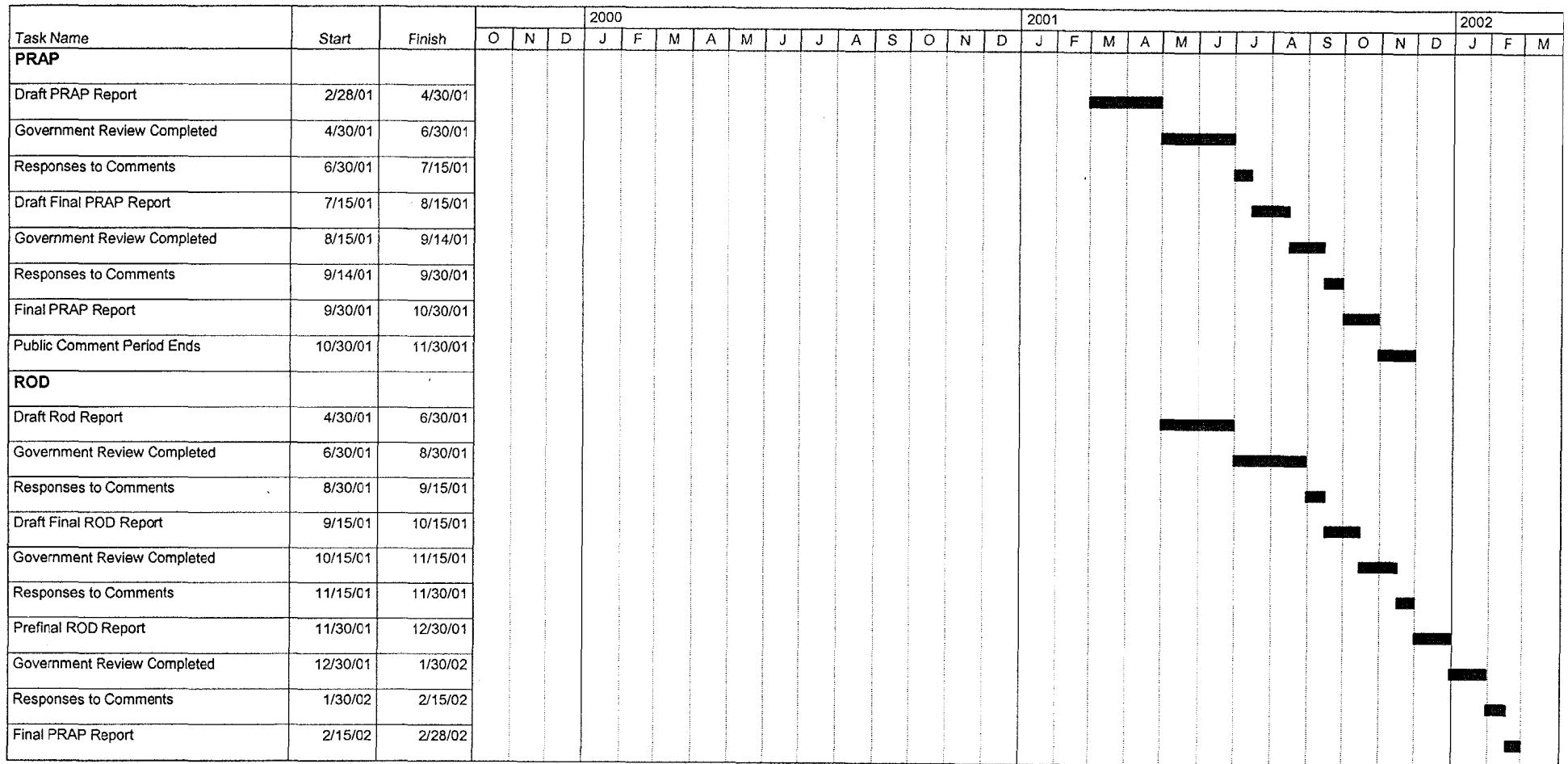


Figure 6-1 - Project Schedule  
Site 84/Building 45 Area  
MCB Camp Lejeune, NC





**FINAL**

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
FIELD SAMPLING AND ANALYSIS PLAN  
SITE 84/BUILDING 45 AREA  
MCB CAMP LEJEUNE, NORTH CAROLINA  
CONTRACT TASK ORDER 0139 (CLEAN II)**

**JUNE 2001**

*Prepared for:*

**DEPARTMENT OF THE NAVY  
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*Under:*

**LANTDIV CLEAN Program  
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## TABLE OF CONTENTS

	<u>Page</u>
<b>1.0 INTRODUCTION.....</b>	<b>1-1</b>
<b>2.0 SITE BACKGROUND.....</b>	<b>2-1</b>
<b>3.0 SAMPLING OBJECTIVES .....</b>	<b>3-1</b>
<b>4.0 SAMPLING LOCATIONS AND FREQUENCY.....</b>	<b>4-1</b>
4.1 Surveying .....	4-1
4.2 Soil Investigation.....	4-1
4.2.1 Sampling Locations.....	4-1
4.2.2 Analytical Requirements .....	4-2
4.3 Groundwater Investigation .....	4-2
4.3.1 Monitoring Well Locations .....	4-3
4.3.2 Analytical Requirements .....	4-3
4.4 QA/QC Samples.....	4-3
4.5 Investigation Derived Waste Handling .....	4-5
<b>5.0 SAMPLE DESIGNATION.....</b>	<b>5-1</b>
<b>6.0 INVESTIGATIVE PROCEDURES .....</b>	<b>6-1</b>
6.1 Soil Sample Collection.....	6-1
6.1.1 Soil Borings Advanced by Direct Push Method .....	6-1
6.1.2 Monitoring Well Boreholes.....	6-1
6.1.3 ENSYS Testing .....	6-2
6.1.4 Monitoring Well Boreholes.....	6-3
6.2 Monitoring Well Installation .....	6-4
6.3 In Situ Slug Tests .....	6-7
6.4 Groundwater Sample Collection .....	6-8
6.4.1 Groundwater Samples Collected from Monitoring Wells.....	6-8
6.5 Decontamination .....	6-9
6.6 Monitoring and Data Collection Equipment .....	6-9
6.7 Land Survey .....	6-10
6.8 Investigation Derived Waste Handling .....	6-10
6.8.1 Responsibilities .....	6-10
6.8.2 Sources of Investigation Derived Wastes.....	6-11
6.8.3 Designation of Potentially Hazardous and Nonhazardous Investigation Derived Wastes.....	6-11
6.8.4 Investigation Derived Waste Sampling and Analysis .....	6-12
6.8.5 Labeling.....	6-12
6.8.6 Container Log.....	6-13
6.8.7 Container Storage.....	6-13
6.8.8 Container Disposition.....	6-13
6.8.9 Disposal of Contaminated Materials .....	6-13

## TABLE OF CONTENTS (Continued)

		<u>Page</u>
<b>7.0</b>	<b>SAMPLE HANDLING AND ANALYSIS.....</b>	<b>7-1</b>
7.1	Sample Preservation and Handling .....	7-1
7.2	Chain-of-Custody .....	7-1
7.3	Field Logbook .....	7-1
<b>8.0</b>	<b>SITE MANAGEMENT.....</b>	<b>8-1</b>
8.1	Field Team Responsibilities .....	8-1
8.2	Reporting Requirements.....	8-1
<b>9.0</b>	<b>REFERENCES .....</b>	<b>9-1</b>

### LIST OF TABLES

- 7-1 Summary of Sampling and Analytical Objectives

### LIST OF FIGURES

- 4-1 Proposed Sampling Locations
- 6-1 Type II Groundwater Monitoring Well (Flush Mount) Construction Diagram

### LIST OF APPENDICES

- Appendix A Soil and Rock Acquisition
- Appendix B Borehole and Sample Logging
- Appendix C Field Screening Procedures for PCBs
- Appendix D Monitoring Well Installation
- Appendix E Well Head Testing
- Appendix F Low Flow Purging and Sampling Procedures for Groundwater Sampling
- Appendix G Groundwater Acquisition
- Appendix H Decontamination of Sampling and Monitoring Equipment
- Appendix I Decontamination of Drilling Rigs and Monitoring Well Materials
- Appendix J On-Site Water Quality Testing
- Appendix K Water Level, Water-Product Level Measurements, and Well Depth Measurements
- Appendix L Photoionization Detector (PID)
- Appendix M Bacharach Combustible Gas/Oxygen Meter and Personal Gas Monitor Carbon Monoxide Meter
- Appendix N Land Survey
- Appendix O Drum Sampling
- Appendix P Wastewater Sample Acquisition
- Appendix Q Sample Preservation and Handling
- Appendix R Chain-of-Custody
- Appendix S Field Logbook

## LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
ASTM	American Society of Testing and Materials
bgs	below ground surface
CLP	Contract Laboratory Program
D	duplicate sample
DOT	Department of Transportation
DP	direct push
DQO	Data Quality Objective
ECBSOPQAM	Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual
ER	Equipment Rinsate
ESD	Environmental Services Division
FB	Field Blank
FY	Fiscal Year
GW	groundwater
ID	inside diameter
IDW	Investigation Derived Waste
IR	Installation Restoration
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
MS/MSD	Matrix Spike/Matrix Spike Duplicate
N	penetration resistance
NFSEC	Naval Facilities Engineering Service Center
NTU	nephelometric turbidity unit
O <sub>2</sub> /LEL -	oxygen/lower explosive limit
OD	outside diameter
PCB	polychlorinated biphenyl
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study

**LIST OF ACRONYMS AND ABBREVIATIONS**  
**(Continued)**

SB	soil boring
SD	sediment
SOP	Standard Operating Procedure
SPT	standard penetration test
SW	surface water
TAL	Target Analyte List
TB	trip blank
TCL	Target Compound List
TCLP	Toxicity Characteristics Leaching Procedure
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
USCS	Unified Soil Classified System
VOA	volatile organic analyses
VOC	volatile organic compounds

## **1.0 INTRODUCTION**

This Field Sampling and Analysis Plan (FSAP) presents the proposed Remedial Investigation (RI) field activities that are to be conducted at Site 84/Building 45 Area at Marine Corps Base (MCB), Camp Lejeune, North Carolina.

Based on an evaluation of the previous investigations that have been performed at Site 84, the extent of PCB contamination in the soil has not been fully defined. Analysis indicates that PCB contamination in the surface soils extends from the lagoon area towards Building 45 (Equipment and Maintenance Shop). A field investigation to fully define the extent of PCB contamination in the soil is proposed. Additionally, investigations are required to evaluate whether the shallow water table aquifer has been affected by site contamination. This will be accomplished by the installation of groundwater monitoring wells in the shallow aquifer and collection of groundwater samples for analysis.

The primary purpose of the FSAP is to provide guidance for all project field activities by describing in detail the sampling and data collection methods to be used to implement the various field tasks identified in the remedial Investigation/Feasibility Study (RI/FS) Work Plan for Site 84. This document also helps to ensure that project activities are carried out in accordance with U.S. Environmental Protection Agency (USEPA) Region IV and Naval Facilities Engineering Service Center (NFESC) practices, so that data obtained during the field investigation are of sufficient quantity and quality to evaluate the nature and extent of contamination in various media, estimate human health and environmental risks, and to evaluate potential technologies for remediation of contaminated media.

## **2.0 SITE BACKGROUND**

A description of the history and setting of Marine Corps Base (MCB), Camp Lejeune, North Carolina and the Site 84 study area is contained in Section 2.0 of the RI/FS Work Plan.

### **3.0 SAMPLING OBJECTIVES**

The sampling and data quality objectives (DQOs) for the field investigation at Site 84 are summarized in Section 3.0 of the RI/FS Work Plan.



## **4.0 SAMPLING LOCATIONS AND FREQUENCY**

This section of the FSAP describes the location and frequency of environmental samples to be collected during the sampling program. Support activities, sampling locations, sample matrix and constituents for analysis are discussed within this section. Sample designation conventions, detailed investigation procedures, and sampling handling and analytical requirements are provided in Sections 5.0, 6.0 and 7.0, respectively.

### **4.1 Surveying**

The site survey will involve the surveying of the site topography, current site features, including main roads, nearby buildings, site utilities, and Northeast Creek. All existing groundwater monitoring wells at Site 84 will be resurveyed for horizontal coordinates and elevation. This will provide a uniform correlation between groundwater level measurements previous and current data.

Prior to commencing the field sampling program, a sampling grid at 50-foot centers will be established within the Site 84 area as shown on Figure 4-1. The points within the grid will be surveyed and flagged. This will allow the location of the soil sampling points to be determined in the field.

The location and elevation of a reference point on top of the PVC riser, and elevation of ground surface will be surveyed for each groundwater monitoring well installed during this investigation.

Survey points will include a latitude coordinate, a longitude coordinate, and an elevation expressed in feet of mean sea level (msl). The vertical accuracy of the survey will be within 0.01 feet and the horizontal accuracy will be within 0.1 feet. All survey points will be correlated to the North Carolina State Plane Coordinate System.

### **4.2 Soil Investigation**

A soil investigation will be conducted at Site 84 to characterize soil quality at the site and to determine the presence or absence of waste materials within the boundary of Site 84. Soil samples will be collected from the grid sampling points using GeoProbe sampling methods to identify and characterize potential soil contamination.

#### **4.2.1 Sampling Locations**

A sampling grid, at 50-foot centers, will be established. USEPA Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup (USEPA, 1986) was used as a guide in determining spacing of grid lines. Using the procedure set forth in this guidance document, based on the radius of sampling (with the center between the lagoon and Building 45) a row spacing of approximately 62 feet was calculated. To facilitate the field survey of the grid lined, a spacing of 50 feet was assumed. This row spacing does, however, provide for less than the required number of sampling points, based on the guidance rational. Sampling will be conducted in the pattern illustrated on Figure 4-1. Additionally, the electric substation located west/southwest of Building 45 will be investigated to determine if there is potential PCB contamination associated with this facility. It is estimated that up to ten surface soil samples will be collected from around the slab. The slab will be evaluated as to the potential for contamination to have migrated beneath the slab. A total of 37 locations will have surface soil samples collected from 0 to 12 inch depth for analysis of PCBs. These soil samples will be analyzed in the field using the ENSYS field screening kits for PCBs. If PCB contamination is detected at the outer points of the grid, sampling will be extended

outward (using the same gridlines) at 50-foot increments until PCBs are “nondetect”. Fifteen to twenty percent of the surface soil samples collected will be submitted to an off-site laboratory for confirmatory PCB analysis.

Based on results of the surface soil analyses, soil borings will be advanced in areas that exhibited PCB contamination to determine the presence or absence of PCBs at depth. All soil samples collected from the soil borings will be screened with a photoionization detector (PID). Subsurface soil samples will be collected from the approximate midpoint between the ground surface and water table and from just above the water table [estimated at 10 to 15 feet below ground surface (bgs)] and analyzed in the field using the ENSYS field screening kit for PCBs. Fifteen to twenty percent of the samples collected from the soil borings will be submitted to an off-site laboratory for confirmatory PCB analyses. Based on the evaluation of field results, additional soil borings may be installed to better define the vertical and horizontal extent of PCB contamination. The location of these borings will be based on detected levels of PCB contamination and apparent data gaps.

It should be noted that, based on current site features, condition of the site, and current activities in the site area, all proposed sampling locations might not be accessible. Sampling locations will be adjusted in the field based on these conditions. Adjusted sampling locations will be as near as possible to the proposed locations. All sampling locations that require field adjustment will be resurveyed for location and elevation.

Based on the results of the soil investigation, an estimated proposed six (6) groundwater monitoring wells may be installed to investigate the surficial groundwater aquifer at the site. Soil borings will be performed at each of the proposed six (6) groundwater monitoring well locations using hollow stem augers. It is estimated that three soil samples will be collected from each of the monitoring well borings. One sample will be collected from the 0 to 12 inch depth, one sample from the approximate midpoint between the ground surface and water table, and one sample from just above the water table.

Section 6.1 presents details on procedures for collecting soils samples using the GeoProbe technique and from the proposed soil boring locations for monitoring well installations.

#### **4.2.2 Analytical Requirements**

Surface and subsurface soil samples will be analyzed in the field using ENSYS PCB Soil Test kits. Sample locations where levels of PCBs are above detection limits for the ENSYS test kits (1.0 mg/kg and 10.0 mg/kg) will be expanded to assess the horizontal and vertical extent of the constituents. Confirmatory samples submitted to the off-site laboratory will be analyzed for TCL PCBs in accordance with Contract Laboratory Program (CLP) protocols.

#### **4.3 Locate Drain(s)**

Subsurface grab soil samples will be analyzed in the field using ENSYS PCB Soil Test kits. Confirmatory samples submitted to the off-site laboratory will be analyzed for TCL PCBs in accordance with CLP protocols.

#### **4.4 Groundwater Investigation**

Based on a review of the RI/FS soil investigation, a groundwater investigation may be performed to assess the impact of detected soil contamination on the shallow aquifer. Information is presented in Section 4.3 and Sections 6.1, 6.2, 6.3 and 6.4 of this FSAP that pertains to a groundwater investigation. This information is included to provide a more complete sampling and analysis plan.

##### **4.4.1 Monitoring Well Locations**

A groundwater investigation will be conducted at Site 84 to determine the presence or absence of contamination in the surficial aquifer resulting from the storage and/or disposal of PCB containing electrical transformers. Up to six (6) shallow groundwater monitoring wells are proposed for this investigation. The locations of these monitoring wells will be determined following the completion of the initial soil investigation. All newly installed wells will be approximately 30 feet deep and will be constructed of 2-inch I.D. PVC pipe, with 15 feet of 0.01-inch slot well screen. Section 6.2 presents specific details on procedures for monitoring well installations.

In order to assess the rate of groundwater migration at the site, it will be necessary to obtain estimates of hydraulic conductivity within the surficial aquifer. In-situ slug tests will be conducted at the new well locations to evaluate horizontal hydraulic conductivity. Rising and/or falling head tests will be performed. Water level recovery data will be evaluated using the most appropriate analysis method for each location. Section 6.3 presents specific details on the procedures for performing in situ slug tests.

##### **4.4.2 Analytical Requirements**

Two rounds of groundwater samples will be collected at Site 84. These sampling rounds will consist of samples collected from the newly installed monitoring wells and any existing wells at Site 84 that are considered appropriate following a review of existing well locations and analyses. Any existing wells included in the sampling events will be redeveloped to insure a representative sample is collected. The first round of samples will be collected approximately one week following development of the newly installed wells. The second round will be collected approximately three months following the first sampling round. Details on the procedures for collecting groundwater samples are presented in Section 6.4. Groundwater samples will be analyzed for TCL PCBs.

#### **4.5 QA/QC Samples**

Quality Assurance/Quality Control (QA/QC) requirements for this investigation are presented in the Quality Assurance Project Plan (QAPP) which is provided as a separate section of the Project Plans. The following QA/QC samples will be collected during field sampling activities:

- **Trip Blanks**

Trip blanks are defined as samples which originate from the analyte-free water taken from the laboratory to the sampling site, kept with the investigative samples throughout the sampling event, and returned to the laboratory with the volatile organic analysis (VOA) samples. One trip blank should accompany each cooler containing samples for volatile organic analysis. The blanks will only be analyzed for volatile organics. The purpose of a trip blank is to determine if samples were contaminated during storage and transportation back to the laboratory.

- Equipment Rinsates (Equipment Blanks)

Equipment rinsates are defined as samples which are obtained by running organic-free water over/through sample collection equipment after it has been cleaned. Equipment rinsates will be collected daily during each sampling event. All rinsate samples will be submitted to analytical laboratory, extraction performed and appropriately stored. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsates, the remaining samples must be analyzed. The results from the rinsates will be used to evaluate the decontamination methods. This comparison is made during data validation and the rinsates are analyzed for the same parameters as the related samples.

One equipment rinsate will be collected per day of field sampling.

- Field Blanks

Organic-free water is taken to the field in sealed containers and poured into the appropriate sample containers at pre-designated locations. This is done to determine if any contaminants present in the area may have an effect on sample integrity. Field blanks should not be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled.

A field blank will also be collected of the potable water used in the decontamination of drilling and sampling equipment.

Two field blanks (ambient condition blanks) will be prepared at the commencement of each sampling event. The field blanks will be prepared by pouring organic-free water directly into a set of sample bottles.

- Field Duplicates

Field duplicates for soil samples are collected concurrently with environmental samples. All samples, except VOAs, are homogenized and split. Volatiles are not mixed, but select segments of soil are taken from the length of the core and placed in 4-ounce glass jars. The duplicates for water samples should be collected simultaneously. The water samples will not be composited.

Confirmatory samples from the ENSYS field screening activities will be collected and submitted at a frequency of 10% of the field screened samples. Field duplicates of soil samples collected from soil borings for laboratory analysis during the field investigation will be collected and submitted at a frequency of 10% of the environmental samples.

- Matrix Spike/Matrix Spike Duplicates (MS/MSD)

MS/MSD samples are collected to evaluate the matrix effect of the sample upon the analytical methodology. A matrix spike and matrix spike duplicate must be performed for each group of samples of a similar matrix

MS/MSD samples will be collected at a frequency of 5 percent.

#### **4.6     Investigation Derived Waste Handling**

Due to the use of the GeoProbe sampling method, little to no solid wastes will be generated during the initial soil investigation. If material is encountered that is deemed potentially hazardous based on visual and/or field measurements/readings, it will be contained in 55-gallon drums and stored on site until sampling and proper disposal can be arranged. Drill cuttings from the installation of the proposed groundwater monitoring wells will be collected and contained in drums or a roll-off box. A rigid storage tank with a capacity of 1000 gallons will be stationed at Site 84 for containing monitoring well development and purge water. A composite soil sample from the drums/roll-off box will be collected and analyzed for full TCLP (organics and inorganics) and RCRA hazardous waste characterization (corrosivity, reactivity, and ignitability). One sample will be collected from the tank and analyzed for full TCL organics and TAL inorganics. Additional details regarding IDW handling and disposal are provided in Section 6.12.

## 5.0 SAMPLE DESIGNATION

In order to identify and accurately track the various samples, all samples collected during this investigation, including QA/QC samples, will be designated with a unique number. The number will serve to identify the investigation, the site, the area within the site, the sample media, sampling location, the depth (soil) or round (groundwater) of sample, and QA/QC qualifiers.

The sample designation format is as follows:

Site Type and Site #-Location-Media/Station # or QA/QC-Depth/Round

An explanation of each of these identifiers is given below.

Site Type	IR = Installation Restoration
Site #	This investigation includes Site 84.
Media	DP = Direct Push (GeoProbe) soil sample SB = Soil Boring (soil sample from a boring) GW = Groundwater SW = Surface Water SD = Sediment
Station #	Each soil test boring or monitoring well will be identified with a unique identification number. The designation "SW" after the station number refers to a shallow well installed within the shallow water-table aquifer. Samples that are being submitted for dissolved metals analyses will be designated by a "D" at the end of the station number designation.
QA/QC	(FB) = Field Blank (D) = Duplicate Sample (following depth/round) (TB) = Trip Blank (ER) = Equipment Rinsate
Depth/Round	Depth indicators will be used for soil samples. The number will reference the depth interval of the sample. For example:  00 = ground surface to 1 foot below ground surface 01 = 1 to 3 feet below ground surface 02 = 3 to 5 feet below ground surface 03 = 5 to 7 feet below ground surface  The year and quarter that groundwater sampling took place will be used as a round indicator. For example:  00 = Year 2000 01 = Year 2001 02 = Year 2002  A = 1 <sup>st</sup> Quarter B = 2 <sup>nd</sup> Quarter C = 3 <sup>rd</sup> Quarter D = 4 <sup>th</sup> Quarter

Under this sample designation format the sample number IR84-GW03SWD-00DD refers to:

<u>IR</u> 84-GW03SWD-00DD	Installation Restoration Site
IR <u>84</u> -GW03SWD-00DD	Site 84
IR84- <u>GW</u> 03SWD-00DD	Groundwater sample
IR84-GW <u>03</u> SWD-00DD	Monitoring well #3
IR84-GW03 <u>SWD</u> -00DD	Shallow well
IR84-GW03SWD- <u>00</u> DD	Dissolved metals sample
IR84-GW03SWD-00 <u>DD</u>	4 <sup>th</sup> Quarter of 2000
IR84-GW03SWD-00DD <u>  </u>	Duplicate (QA/QC) sample

The sample designation IR84-DP11-00D refers to:

<u>IR</u> 84-DP11-00D	Installation Restoration Site
IR <u>84</u> -DP11-00D	Site 84
IR84- <u>DP</u> 11-00D	GeoProbe Sample
IR84-DP <u>11</u> -00D	Sample Location #1
IR84-DP11- <u>00</u> D	Sample depth interval 0 to 12"
IR84-DP11-00 <u>D</u>	Duplicate (QA/QC) sample

This sample designation format will be followed throughout the project. Required deviations to this format in response to field conditions will be documented.

## **6.0 INVESTIGATIVE PROCEDURES**

The investigative procedures to be used for Site 84 will be discussed in the following subsections. These procedures include soil sample collection, monitoring well installation, in situ slug tests, groundwater sample collection, surface water sample collection, sediment sample collection, surveying, water level measurements, decontamination procedures, and handling of site investigation derived wastes. Note that all of these procedures will follow the field methods described in the USEPA, Region IV, Environmental Services Division (ESD), Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (ECBSOPQAM), February 1, 1991. Additional guidance from other sources such as ASTM may be used, but if the ASTM and ESD methods are in conflict, the ESD procedure will be used.

### **6.1 Soil Sample Collection**

Surface and subsurface soil samples will be collected throughout Site 84. Soil samples will be collected from borings advanced by a drilling rig and during the installation of monitoring wells. All ground penetration locations will receive utility clearance from the appropriate on-base personnel. Appendix A contains Baker's standard operating procedures (SOPs) for soil sample acquisition.

#### **6.1.1 Surface Soil Samples**

All surface soil samples will be collected from the top 12-inches of soil using stainless steel trowels or sampling spoons. Vegetation and stones will be removed before sampling. Samples will be placed directly into new plastic bags for transport to the field testing area. Samples will be field screened using the ENSYS test kit for PCBs.

#### **6.1.2 Soil Borings Advanced by Direct Push Method**

Surface and subsurface soil samples will be collected from borings advanced by a direct-push soil sampler. Soil borings will either be advanced by a truck mounted drilling rig, a pick-up truck-mounted rig, or by a hand sampler unit. All boring locations will receive utility clearance from the appropriate on-base personnel or from a private utility locating company.

Soil samples from locations advanced either by a direct-push rig, or by hand will be collected using a GeoProbe "Macro-Core Sampler" or "Large Bore Soil Sampler". Some borings may be difficult to access by a truck mounted rig. In those instances, the samples will be collected using the hand sampler.

The Macro-Core Sampler is a 48 inch long, stainless-steel tube with a 2 inch OD. Threaded to the base is a 1-1/2 inch inside diameter (ID) cutting shoe. Soil samples are collected in a 45 inch long by 1-1/2 inch wide acetate liner that is inserted into the tube. Although the sampler is capable of collecting 45 inch long samples, the sampler will be driven 24 inches for higher percentage recoveries.

The Large Bore Sampler is a 24 inch long, stainless-steel tube with a 1-3/8 inch OD. Attached at its base is a 1-1/16 inch ID cutting shoe. Soil samples are collected in a 22-inch long by 1-1/8 inch wide acetate liner that is inserted into the tube.



Samples will be collected continuously from the ground surface to the water table [estimated to be at a depth of 10 - 15 feet below ground surface (bgs)]. Soils will be classified according to the Unified Soil Classification System (USCS). Soil sample descriptions will be recorded in the field geologist's notebook. Appendix B presents the SOP for Borehole and Sample Logging.

Shallow soil samples will be collected using the GeoProbe samplers. The following procedure will be used for collecting samples:

1. The direct-push sampler will be placed on the ground surface. The sampler will be driven 24 inches by the truck-mounted hydraulic drive assembly or by a hand-held drive hammer. Once at the desired depth, the sampler will be pulled from the hole.
2. The sampler will be disassembled, and the liner containing the sample will be handed to the geologist for logging and, as necessary, containerization for submittal for chemical analysis.
3. The sampler tube and cutting shoe will be decontaminated following procedures outlined in Section 6.9, and then reassembled using a new liner.
4. Repeat Steps 1, 2, and 3 until the desired, final depth is reached.

#### **6.1.3 ENSYS Testing**

An Enzyme-Linked Immunosorbent Assay (ELISA) field screening kit will be utilized in the field for PCB contaminated soil. The test kit has a minimum detection limit of 1.0 mg/kg, which is adequate for this site. The manufacturer will provide the field test kit with the following action levels, 1.0 mg/kg and 10.0 mg/kg. These action levels have been established to inform the data users of the presence or absence of PCBs, and to delineate the extent of contamination based on the action levels established as part of the Remedial Investigation. Because these tests are specific for PCBs, no interferences are expected. These tests have an accuracy of 95% for samples testing positive.

Surface soil samples will be collected by stainless steel trowel or spoon, as noted in Section 6.1.1, from the established sampling points (refer to Figure 4-1). Subsurface soil samples will be collected from soil borings using the direct-push method as presented in Section 6.1.2. Following collection, each sample will be homogenized to ensure that the sample is mixed in a manner that provides uniformity throughout the sample prior to placing it in an appropriate container. This procedure of sample homogenizing will also ensure that the soil sample is representative of that specific interval. After homogenizing, a representative amount of sample will be placed in a plastic bag and cooled to 4° C. Once the required number of samples are collected, 10 grams from each sample will be selected for analysis via the ELISA screening technique; the results of each sample will establish whether additional sampling is needed to better define the extent of contamination. The screening procedures for PCBs are identified in Appendix C.

Fifteen to twenty percent of the collected samples (detects and non-detects) will be sent to an off-site laboratory for confirmatory analysis of PCBs. The portion sent to the laboratory will be acquired from the homogenized sample and placed in the appropriate glass container; this will ensure that the laboratory portion is identical in composition to the portion, which was screened with the ELISA kit. Standard chain-of-custody documentation will accompany confirmatory samples to the analytical laboratory. The results of the confirmatory sampling will verify the extent of contamination in the Site 84/Building 45 Area.

#### 6.1.4 Monitoring Well Boreholes

Soil samples from monitoring well borings, advanced by a drilling rig using hollow stem augers, will be collected using a split-spoon sampler. A split-spoon sampler is a steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. This device can be driven into unconsolidated materials using a drive weight connected to the drilling rig. A split-spoon sampler (used for performing Standard Penetration Tests) is two inches outer diameter (OD) and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively. Split-spoons capable of obtaining 24-inch long samples will be utilized during this investigation.

Split-spoon samples will be collected continuously from the ground surface to approximately 12 feet below the ground, top of the water table, in each monitoring well boring. The physical characteristics of the samples will be described by the site geologist. The soil in the sampler will be classified according to the Unified Soil Classification System (USCS) (refer to Appendix B). Soil sample descriptions will be recorded in the field geologist's notebook.

Selected split-spoon samples will be submitted to the laboratory for analysis. Soil samples will be collected continuously in 2-foot increments from the ground surface to the top of the water table. Below the water table, soil samples may be collected at 5-foot intervals, at the discretion of the geologist.

The following procedures for collecting soil samples in split-spoons will be used:

1. The surface sample will be collected by driving the split-spoon with blows from a 140-pound hammer freely falling 30 inches in accordance with SOP F102 Soil and Rock Sample Acquisition (Appendix A).
2. Advance the borehole to the desired depth using hollow stem auger drilling techniques. The split-spoon will be lowered into the borehole inside the hollow stem auger (this will ensure that undisturbed material will be sampled).
3. Drive the split-spoon using procedures outlined in 1 above.
4. Repeat this operation until the borehole has been advanced to the selected depth. Split-spoon samples will be collected continuously until groundwater is encountered.
5. Record in the field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance,  $N$ . If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of the second and third 6-inch increments will be used to calculate the penetration resistance. (Refusal of the SPT will be noted as 50 blows over an interval equal to or less than 6-inches; the interval driven will be noted with the blow count.)

6. Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Upon opening the spoon sampler, PID readings will be taken. Sections of the soil sample will be opened so that unexposed soil can be screened with the PID. Describe the recovery (length), composition, structure, consistency, color, condition, etc., of the recovered soil; then put into sample jars.
7. Split-spoon samplers shall be decontaminated after each use and prior to the initial use at a site according to procedures outlined in Section 6.9.

The following procedures are to be used for soil samples submitted to the laboratory:

1. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed, in a stainless steel bowl with stainless steel spoons, as thoroughly as possible to ensure that the sample is as representative as possible of the sample interval.
2. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the field logbook. In addition, label, tag, and number the sample bottle(s) as outlined in Section 7.0.
3. Pack the samples for shipping. Attach seal to the shipping package. Chain-of-Custody Forms and Sample Request Forms will be properly filled out and enclosed or attached (Section 7.0).
4. Decontaminate the split-spoon sampler as described in Section 6.9. Replace disposable latex gloves between sample stations to prevent cross-contamination of samples.

## **6.2 Monitoring Well Installation**

Shallow monitoring wells will be installed to monitor the shallow (water table) water-bearing zone. It is estimated that these wells will be installed from 15 to 30 feet. Procedures for the installation and construction of shallow monitoring wells are presented below (see Figure 6-1):

- All monitoring well locations will be approved by the Marine Corps Base Camp Lejeune Partnering Team. The well locations shall be free of underground and/or overhead utility lines.
- A borehole will be advanced by a drilling rig using hollow stem augers. Initially, the boreholes will be advanced with 3-1/4-inch I.D. augers. After the borehole has been advanced to its final depth, the borehole will be overdrilled with 6-1/4-inch I.D. augers (for well installation only).
- Soil (split spoon) samples will be collected continuously during borehole advancement. Samples will be collected according to the procedures outlined in Section 6.1.2.
- Upon completion of the borehole to the desired depth, monitoring well construction materials will be installed (inside the hollow stem augers).

- PVC is the material selected for monitoring well construction. It was selected on the basis of its low cost, ease of use and flexibility. The USEPA has accepted the use of PVC as well construction material in the past; however, the USEPA could require documented justification for the use of this material as set forth in Appendix D of this FSAP.
- Fifteen feet of 2-inch I.D., Schedule 40, #10 slot (0.010 inch) screen with a bottom cap will be installed. The screen will be connected to threaded, flush-joint, PVC riser. The riser will extend to the surface. A PVC slip-cap vented to the atmosphere, will be placed at the top of the riser. The top of the well screen will be placed such that two feet of the screen (as subsurface conditions permit) extends above the groundwater table to allow for seasonal groundwater fluctuations.
- The annular space around the screen will be backfilled with a well-graded medium to coarse sand (No. 1 or No. 2 Silica Sand) as the hollow-stem augers are being withdrawn from the borehole. Sand shall be placed from the bottom of the boring to approximately two feet above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.
- A sodium bentonite seal at least 24-inch thick, unless shallow groundwater conditions are encountered, will be placed above the sand pack. The bentonite shall be allowed to hydrate for at least 8 hours before further completion of the well.
- The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of either two parts sand per one part of cement and water, or three to four percent bentonite powder (by dry weight) and seven gallons of potable water per 94 pound bag of portland cement.
- The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded in the field logbook.
- The monitoring well shall be completed at the surface using a "flush" man-hole type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete pad, a minimum of 4-feet by 4-feet by 6-inches, extending two feet below the ground surface in the annular space and set two inches into the ground elsewhere. If water table conditions prevent having a 24-inch bentonite seal and the concrete pad as specified, the concrete pad depth should be decreased. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.
- All wells will have a locking cap fitted to the PVC riser.

Figure 6-1 depicts a typical Type II flush mount shallow monitoring well construction diagram.

Appendix D contains the SOPs for monitoring well installations.

All monitoring wells (i.e., new and existing) will be developed as specified in the ECBSOPQAM. The purposes of well development is to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation.

Well development shall not be initiated until a minimum of 48 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Shallow wells typically are developed using bailers or low-yield pumping in combination with surging using a surge block. Selection of a development device will be dependent on conditions encountered during monitoring well installation.

All wells shall be developed until well water runs relatively clear of fine-grained materials. Note that the water in some wells does not clear with continued development. Typical limits placed on well development may include any one of the following:

- Clarity of water based on turbidity measurements [typically less than 50 Nephelometric Turbidity Units (NTU)]
- A maximum time period (typically one hour for shallow wells)
- A maximum well volume (typically three to five well volumes)
- Stability of pH, specific conductance and temperature measurements (typically less than 10 percent change between three successive measurements)

A record of the well development shall be completed to document the development process. Section 6.10 provides information on the use of monitoring and data collection equipment for water level measurements, pH, specific conductance, temperature and turbidity.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval.

### **6.3     In Situ Slug Tests**

In situ slug tests will be performed in the newly installed wells at Site 84. Both falling head and rising head procedures will be performed in the wells. The performance of in situ slug tests will include the following procedures:

1. Measure the static groundwater level and depth of well. Record all measurements in the field notebook.
2. Install the data logger transducer. We will be using an IN SITU Hermit 2000 data logger. The transducer should be positioned approximately one foot off the bottom of the well.

3. Set the parameters for the test as per the instructions provided with the data logger. Note that the rate for taking readings should be set on the logarithmic scale. This will collect readings at the fastest rate at the start of the test when changes in the groundwater level are most rapid, and significant in the analysis of the data.
4. Key in the coefficients for the specific transducer being used.
5. Make sure that all settings are correct.
6. Secure the nylon cord to the solid slug. Measure off a mark on the nylon cord that will place the bottom of the slug a minimum of one foot above the transducer.
7. Press the start button and immediately lower the solid slug into the well to the mark on the cord to begin the falling head test. Falling head tests are only valid if the static groundwater level in the well is above the sand pack. As the well installation sets the top of the well screen approximately 2 feet above the groundwater level (to allow for seasonal fluctuations in groundwater), falling head test data will be invalid. The falling head test procedure is still performed initially as part of the in situ slug test as this is the most practical and efficient way to accurately perform the rising head test. Specifics about the in situ slug tests performed as part of the RI will be addressed in the RI/FS Report.
8. During the test, groundwater level measurements can be taken with a water level meter to verify the fall in water level towards static.
9. Continue the test until groundwater is within 90 to 100% of the static water level of the well at the start of the test. Set the data logger to begin a step (as per the instrument instructions).
10. Immediately after beginning the step, remove the slug to begin the rising head test.
11. Again take groundwater level measurements with a water level meter to verify the rise in water level to static.
12. The test can be terminated when the groundwater level has returned to within 90 to 100% of the static water level measured at the start of the test.
13. The transducer and cable should be decontaminated with laboratory grade soap and distilled water upon completion of each well testing.
14. At the end of each days testing, the data logger test files should be downloaded through a laptop computer onto a disc. A backup disk should also be made of the projects slug test data files.

The data obtained from the in situ slug tests will be used in connection with HydroSolve Inc.'s AQTESOLV (Aquifer Test Solver) for Windows program to calculate hydraulic conductivity values at the specific wells tested. Appendix E presents the SOP (402) for Slug Testing.

## **6.4 Groundwater Sample Collection**

### **6.4.1 Groundwater Samples Collected from Monitoring Wells**

Groundwater samples will be collected from newly installed monitoring wells on site. Groundwater is relatively shallow at MCB Camp Lejeune; therefore, purging and sampling will be performed using a peristaltic pump.

A number of recent studies have demonstrated that low-flow purging and sampling is preferable to bailing or high-flow purging and sampling. High-rate pumping is described as a rate greater than, or similar to, the development rate. Some findings include:

- High-flow pumping and bailing may overdevelop a well, causing damage to the well and filter pack (USEPA, 1992).
- High-flow pumping and bailing may disturb accumulated corrosion/reaction products, or sediment (USEPA, 1992), or potentially mobilize particulate or colloidal matter from the formation (Barcelona, Wehrmann and Varljen, 1994).
- High-flow pumping and bailing may cause loss of VOCs. The velocities at which groundwater enters a bailer can actually correspond to unacceptably high purge rates (USEPA, 1992).
- The use of bailers can result in composite averaging by mixing of water across the screen interval (Barcelona, Wehrmann and Varljen, 1994), resulting in unreproducible and unrepresentative data.

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well.
3. Lower purging equipment (submersible pump [RediFlo-27 low yielding pump]) into the well to the depth of the mid-point of the well screen and begin water removal. Purged water will be temporarily stored in DOT-approved 55-gallon drums. Final containment of purged water is addressed in Section 6.12.
4. Measure the rate of discharge using a bucket and stopwatch.
5. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.



6. Record measurements of pH, specific conductance, temperature, and turbidity during purging to ensure the groundwater stabilizes. Generally, these measurements are made after each well volume purged.
7. Pump groundwater directly into the laboratory-supplied sample bottles.

Sample preservation handling procedures are outlined in Section 7.0.

Appendix F presents the Low Flow Purging and Sampling Procedure for Groundwater Sampling. Appendix G presents the SOP for groundwater sampling.

## **6.5 Decontamination**

Equipment and materials that require decontamination fall into two broad categories:

1. Field measurement, sampling, and monitoring equipment (e.g. water level meters, bailers, split-spoon samplers, hand auger buckets, stainless steel spoons, etc.)
2. Machinery, equipment, and materials (e.g. drilling rigs, backhoes, drilling equipment, monitoring well materials, etc.)

Appendices H and I detail procedures for decontaminating the two categories of equipment and materials, respectively.

## **6.6 Monitoring and Data Collection Equipment**

Field support activities and investigations will require the use of monitoring and data collection equipment. Specific conductance, temperature, pH and turbidity readings will be recorded during groundwater and surface water sample collection. In addition, similar specific conductance and pH readings will be recorded during well development. Appendix J, On-Site Water Quality

Testing, provides specific procedures for collecting conductance, temperature, pH and turbidity readings.

Additional monitoring well information may be obtained using water level meters, water-product level meters, and well depth meters. The operation and various uses of this data collection equipment is provided in Appendix K.

Health and safety monitoring and environmental media screening will be conducted using a photoionization detector (PID) and a combustible gas/oxygen meters (O<sub>2</sub>/LEL). The operation and use of the PID is described in Appendix L. The Bacharach O<sub>2</sub>/LEL meter will also be used during the sampling program, primarily to monitor health and safety conditions. Appendix M provides a description of the Bacharach O<sub>2</sub>/LEL meter and operating procedures.

## **6.7 Land Survey**

Site 84 will require survey information. Horizontal and vertical survey tolerances are addressed within the survey requirements under Section 4.0. Appendix N provides a more detailed description of survey procedures and surveyor qualifications.

## **6.8 Investigation Derived Waste Handling**

The following sections deal with the responsibilities, sources, containerization, sampling and analysis, and disposal of Investigation Derived Wastes (IDW). These wastes include soil from borings, groundwater from developing and purging monitoring wells, decontamination fluids, and personal protection equipment.

### **6.8.1 Responsibilities**

LANTDIV - Atlantic Division, Naval Facilities Engineering Command (LANTDIV) or the facility must ultimately be responsible for the final disposition of site wastes. As such, a LANTDIV or MCB Camp Lejeune representative will sign waste disposal manifests as the generator of the material, in the event off-site disposal is required. However, it may be the responsibility of Baker, depending on the contingency discussions during execution of the investigation, to provide assistance to LANTDIV in arranging for final disposition and preparing manifests.

Baker Project Manager - It is the responsibility of the Baker Project Manager to work with the LANTDIV-Technical Representative in determining the final disposition of site investigation wastes. The Baker Project Manager will relay the results and implications of the chemical analysis of waste or associated material, and advise on the regulatory requirements and prudent measures appropriate to the disposition of the material. The Baker Project Manager also is responsible for ensuring that field personnel involved in site investigation waste handling are familiar with the procedures to be implemented in the field, and that all required field documentation has been completed.

Baker Field Team Leader - The Baker Field Team Leader or Site Manager is responsible for the on site supervision of the waste handling procedures during the site investigations. The Baker Field Team Leader also is responsible for ensuring that all other field personnel are familiar with these procedures.

### **6.8.2 Sources of Investigation Derived Wastes**

Field investigation activities often result in the generation and handling of potentially contaminated materials that must be properly managed to protect the public and the environment, as well as to meet legal requirements. These wastes may be either hazardous or nonhazardous in nature. The nature of the waste (i.e., hazardous or nonhazardous) will determine how the wastes will be handled during the field investigation.

The sources of waste material depend on the site activities planned for the project. The following types of activities or sources, typical of site investigations, may result in the generation of waste material which must be properly handled:

- Drilling and monitoring well construction (drill cuttings)
- Mud rotary drilling (contaminated mud)
- Excavated soils from trenches and test pits
- Monitoring well development (development water)
- Groundwater sampling (purge water)
- Aquifer pump tests (potentially contaminated groundwater)
- Heavy equipment decontamination (decontamination fluids)
- Sampling equipment decontamination (decontamination fluids)
- Personal protection equipment (health and safety disposables)

### **6.8.3 Designation of Potentially Hazardous and Nonhazardous Investigation Derived Wastes**

Wastes generated during the field investigation can be categorized as either potentially hazardous or nonhazardous in nature. The designation of such wastes will determine how the wastes are handled. The criteria for determining the nature of the waste, and the subsequent handling of the waste is described below for each type of anticipated investigative waste.

#### **6.8.3.1 Drill Cuttings**

Drill cuttings will be generated during the augering of monitoring well boreholes. As the borehole is augered, collected soil samples will be monitored with an HNu photoionization (PID) unit for organic vapors and notes made on the physical appearance of the soils. Cuttings that do not indicate elevated levels of organics or have visual signs of contamination will be placed on polyethylene sheeting and backfilled into the borehole following completion of the drilling. Cuttings which, by their appearance or organic vapor readings, appear to be contaminated will be containerized in DOT approved drums for temporary storage on site, and subsequent treatment and/or disposal.

#### **6.8.3.2 Monitoring Well Development and Purge Water**

All development and purge water shall be containerized in tankers, or large (250-gallon) containers. Groundwater development/purge water that exhibits elevated HNu readings should be kept separate from water that does not exhibit elevated levels for purposes of subsequent treatment and/or disposal.

#### **6.8.3.3 Decontamination Fluids**

Equipment and personal decontamination fluids shall be containerized in 55-gallon drums. The fluids shall be collected from the decon/wash pads.

#### **6.8.3.4 Personal Protective Equipment**

All personal protective equipment (i.e., tyveks, gloves, and other health and safety disposables) shall be placed in garbage bags and disposed of in trash dump boxes.

### **6.8.4 Investigation Derived Waste Sampling and Analysis**

Composite samples shall be collected from the drums containing apparent contaminated soil cuttings. These samples will be analyzed for full TCLP (organics and inorganics), PCBs, and RCRA hazardous waste characterization (corrosivity, reactivity, and ignitability). Appendix O contains procedures for collecting samples from drums.

For each tanker or container of development/purge water, a sample shall be collected for full TCL organic and TAL inorganic analysis. Procedures for collecting waste water samples are presented in Appendix P.

Decontamination fluids collected during the investigation shall be sampled and analyzed for full TCL organics and TAL inorganics.

### **6.8.5 Labeling**

If 55-gallon drums are used to containerize drill cuttings, the containers will be consecutively numbered and labeled by the field team during the site investigation. Information shall be stenciled in paint on both the container lid and side. Container labels shall include, at a minimum:

- LANTDIV CTO (number)
- Project name
- Drum number
- Boring or well number
- Date
- Source
- Contents
- Contractor - Baker Environmental, Inc.
- Baker Project Manager- Mr. Jeffrey P. Tepsic

If laboratory analysis reveals that containerized materials are hazardous or contain PCBs, additional labeling of containers may be required. The Project Manager will assist LANTDIV in additional labeling procedures, if necessary, after departure of the field team from the facility. These additional labeling procedures will be based upon the identification of material present; USEPA regulations applicable to labeling hazardous and PCB containing wastes are contained in 40 CFR Parts 261, 262, and 761.

### **6.8.6 Container Log**

A container log shall be maintained in the site logbook. The container log shall contain the same information as the container label plus any additional remarks or information. Such additional information may include the identification number of a representative laboratory sample. MCB IRD/EMD will be informed of the status of all IDW drums stored on a regular basis.

### **6.8.7 Container Storage**

Containers of site investigative wastes shall be stored on site or in a specially designated secure area that is managed by the MCB Camp Lejeune Environmental Management Department (EMD) until disposition is determined. All containers shall be covered with plastic sheeting to provide protection from the weather.

If the laboratory analysis reveal that the containers hold hazardous or PCB wastes, additionally required storage security may be implemented; Baker will coordinate with LANTDIV and/or the Activity any additional measures that may need to be taken to insure that the containerized IDW is secure and meets applicable Federal regulations.

Baker will assist LANTDIV in devising the storage requirements, which may include the drums being staged on wooden pallets or other structures to prevent contact with the ground and being staged to provide easy access. Weekly inspections by facility personnel of the temporary storage area may also be required. These inspections may assess the structural integrity of the containers and proper container labeling. Also, precipitation that may accumulate in the storage area may need to be removed. These weekly inspections and whatever precipitation removal is necessary shall be recorded in the site logbook.

#### **6.8.8 Container Disposition**

The disposition of the containers of site investigation generated wastes shall be determined by LANTDIV, with the assistance of Baker, as necessary. Container disposition shall be based on quantity of materials, types of materials, and analytical results. If necessary, specific samples of contained materials may be collected to identify further characteristics which may affect disposition. Typically, container disposition will not be addressed until after receipt of applicable analytical results; these results are usually not available until long after completion of the field investigation at the facility.

#### **6.8.9 Disposal of Contaminated Materials**

Actual disposal methods for IDW will be determined following receipt of chemical analyses. The usual course will be a contractor specialist retained to conduct the disposal. However, regardless of the mechanism used, all applicable Federal, state, and local regulations shall be observed. USEPA regulations applicable to generating, storing, and transporting PCB or hazardous wastes are contained in 40 CFR Parts 262, 263 and 761, and 49 CFR (DOT Regulations).

Another consideration in selecting the method of disposal of contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable on-site disposal or treatment structure is expected, contaminated materials generated during the site investigation may be stored at the site for treatment/disposal with other site materials. In this case, the initial containment (i.e., drums or other containers) shall be evaluated for use as long-term storage. Also, other site conditions, such as drainage control, security and soil types must be considered in order to provide proper storage.

## **7.0 SAMPLE HANDLING AND ANALYSIS**

Field activities will be conducted in accordance with USEPA Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (May, 1996).

The number of samples, analytical methods, data quality level and laboratory turnaround times are presented in Table 7-1. Container and preservation requirements, and sample holding times are provided in Section 6.1 of the Quality Assurance Project Plans (QAPP).

### **7.1 Sample Preservation and Handling**

Sample preservation and handling procedures will be adhered to during the field program in order to maintain sample integrity. Preservation and handling procedures are provided in Appendix Q of this FSAP.

### **7.2 Chain-of-Custody**

Chain-of-custody procedures will be followed throughout the field program for samples submitted to an off site laboratory for analysis to ensure a documented traceable link between measurement results and the sample or parameter they represent. These procedures are intended to provide a legally acceptable record of sample collection, identification, preparation, storage, shipping and analysis. Chain-of-custody procedures to be followed during the field program are contained in Appendix R. For ENSYS field screening samples, a sample log will be kept which will include sample number, date and time sample was collected, date and time sample was field screened, and screening results.

### **7.3 Field Logbook**

Field logbooks will be used to record sampling activities and information. Entries will include general sampling information so that site activities may be reconstructed. In addition to the field logbook, field forms (e.g., boring logs, well development records, etc.) will be completed as support documentation for the field logbook. Appendix S describes the general format of the field logbook and applicable field forms. Field documentation will follow the SOP set forth in the USEPA Region IV Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual (May, 1996).

## **8.0 SITE MANAGEMENT**

This section outlines the responsibilities and reporting requirements of on-site personnel.

### **8.1 Field Team Responsibilities**

The field portion of this project will consist of one field team. All field activities will be coordinated by a Site Manager. The Site Manager will ensure that all field activities are conducted in accordance with the Project Plans (i.e., Work Plan, Field Sampling and Analysis Plan, Quality Assurance Project Plan and Health and Safety Plan).

The Field Team will employ one or more drilling rigs for the direct push and monitoring well installations. Each rig(s) will be supervised by a Baker geologist. Two sampling technicians will be assigned to the field team. One of the sampling technicians will serve as the Health and Safety Officer.

### **8.2 Reporting Requirements**

The Site Manager will report to the Project Manager on field activities as the field investigation progresses. The Site Manager will include, at a minimum, the following:

- Baker personnel on site.
- Other personnel on site
- Major activities performed/accomplished
- Subcontractor quantities (e.g., drilling footage).
- Samples collected.
- Problems encountered.
- Planned activities.

A Daily Activity Log will be completed for each drill crew utilized for the field investigation. This daily log will be completed by the field geologist overseeing the specific drill crew. The Daily Activity Log is based on the items presented in the Basic Ordering Agreement (BOA) agreed to by the subcontractor.

The Site Manager will receive direction from the Project Manager regarding changes in scope of the investigation. All changes in scope will be discussed and agreed upon by LANTDIV, Camp Lejeune EMD, USEPA Region IV and the North Carolina DENR.



## 9.0 REFERENCES

Environmental Science and Engineering, Inc. (ESE), 1990. Final Site Summary Report, Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Facilities Engineering Command Atlantic Division. ESE Project No. 49-02036. September 1990.

U.S. Department of the Navy (DON), 1992. Navy/Marine Corps Installation Restoration Manual. February 1992.

U.S. Environmental Protection Agency, 1987. Data Quality Objectives for Remedial Response Activities. OSWER Directive 9355.0-7B. EPA/540/G-87/003. March 1987.

U.S. Environmental Protection Agency (USEPA), Region IV, 1996. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. May 1996.

U.S. Environmental Protection Agency (USEPA), 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Interim Final. Office of Emergency and Remedial Response, OSWER Directive 9344.3-01. EPA/540/G-89-004.

U.S. Environmental Protection Agency (USEPA), 1986. Field Manual for Grid Sampling of PCB Spill Sites to Verify Cleanup. Office of Toxic Substances. EPA/560/5-86-017. May, 1986.

Water and Air Research, Inc. (WAR), 1983. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity. April 1983.

## **TABLES**

TABLE 7-1

SUMMARY OF SAMPLING AND ANALYTICAL OBJECTIVES  
 SITE 84/BUILDING 45 AREA  
 REMEDIAL INVESTIGATION/FEASIBILITY STUDY, CTO-0139  
 MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA

Study Area	Investigation	Baseline No. of Samples <sup>(1)</sup>	Analysis	Data Quality Objective	Analytical Method	Laboratory Turnaround
Site 84/Building 45 Area	Surface Soil Sampling	96 locations	ENSYs PCB TCL PCBs	II III	SW-846 Method 4020 CLP/SOW	Routine <sup>(4)</sup>
	Soil - Well Borings	6 borings/2 samples per boring	ENSYs PCB TCL PCBs	III III	CLP/SOW CLP/SOW	Routine Routine
	Groundwater - Two rounds sampling	6 new shallow monitoring wells 4 existing shallow monitoring wells	TCL PCBs	III III	CLP/SOW CLP/SOW	Routine Routine
	IDW - Soil	2	TCL PCBs TCLP <sup>(5)</sup> RCRA <sup>(6)</sup>	III	SW-846	Routine
	IDW - Water	2	TCL Organics <sup>(2)</sup> TAL Metals (total/dissolved) <sup>(3)</sup>	III	CLP/SOW CLP/SOW	Routine Routine

Notes:

<sup>(1)</sup> Baseline number of samples do not include QA/QC samples.<sup>(2)</sup> TCL Organics: volatile organics, semivolatile organics, pesticides/PCBs<sup>(3)</sup> TAL Metals:

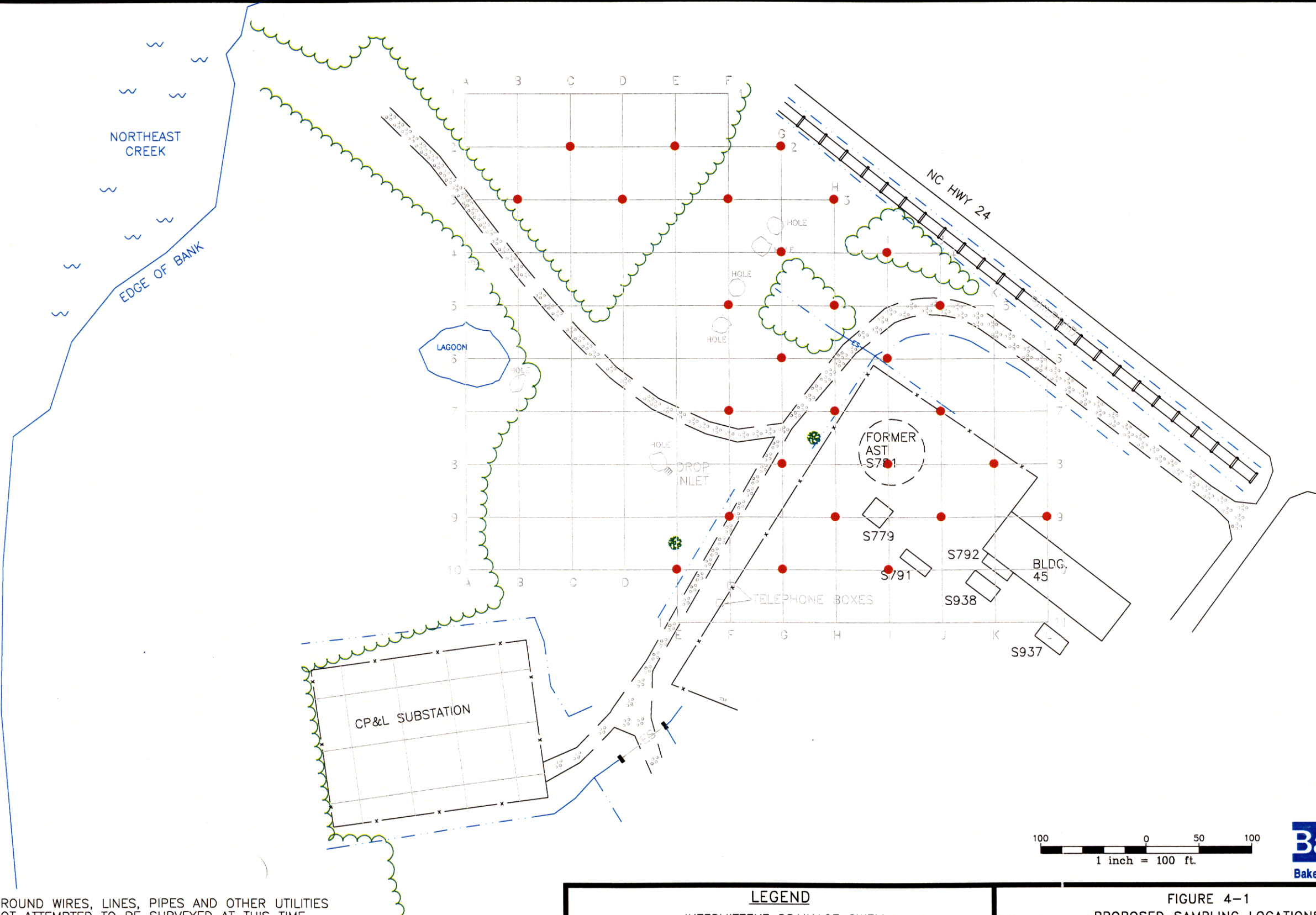
Aluminum	EPA 3010/EPA 200.7	Cobalt	EPA 3010/EPA 200.7	Potassium	EPA 3010/EPA 200.7
Antimony	EPA 3010/EPA 200.7	Copper	EPA 3010/EPA 200.7	Selenium	EPA 3020/EPA 270.2
Arsenic	EPA 3020/EPA 206	Iron	EPA 3010/EPA 200.7	Silver	EPA 3010/EPA 200.7
Barium	EPA 3010/EPA 200.7	Lead	EPA 3020/EPA 239	Sodium	EPA 3010/EPA 200.7
Beryllium	EPA 3010/EPA 200.7	Magnesium	EPA 3010/EPA 200.7	Thallium	EPA 3020/EPA 279
Cadmium	EPA 3010/EPA 200.7	Manganese	EPA 3010/EPA 200.7	Vanadium	EPA 3010/EPA 200.7
Calcium	EPA 3010/EPA 200.7	Mercury	EPA 3010/EPA 245.1	Zinc	EPA 3010/EPA 200.7
Chromium	EPA 3010/EPA 200.7	Nickel	EPA 3010/EPA 200.7		

<sup>(4)</sup> Routine analytical turnaround is 28 days following receipt of samples.<sup>(5)</sup> TCLP - VOAs, SVOAs, Pesticides, Herbicides, and Metals<sup>(6)</sup> RCRA - Corrosivity, Reactivity, and Ignitability (React Sulfide, React Cyanide)

## **FIGURES**

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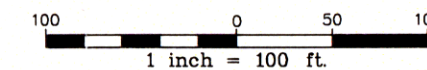
## NOTES:

- 1.) UNDERGROUND WIRES, LINES, PIPES AND OTHER UTILITIES WERE NOT ATTEMPTED TO BE SURVEYED AT THIS TIME.
- 2.) THIS FIGURE PRESENTS THE INITIAL PROPOSED SAMPLING PROGRAM. BASED ON RESULTS OF THE SURFACE SOIL FIELD PCB SCREENING RESULTS, ADDITIONAL LOCATIONS WITHIN OR OUTSIDE THE ESTABLISHED GRID WOULD BE SAMPLED AND SCREENED. ADDITIONAL SAMPLING WOULD BE PERFORMED ON EXTENDED GRID POINTS AT 50-FOOT CENTERS AND UNTIL PCB SCREENING RESULTS INDICATE "NON-DETECT".

## LEGEND

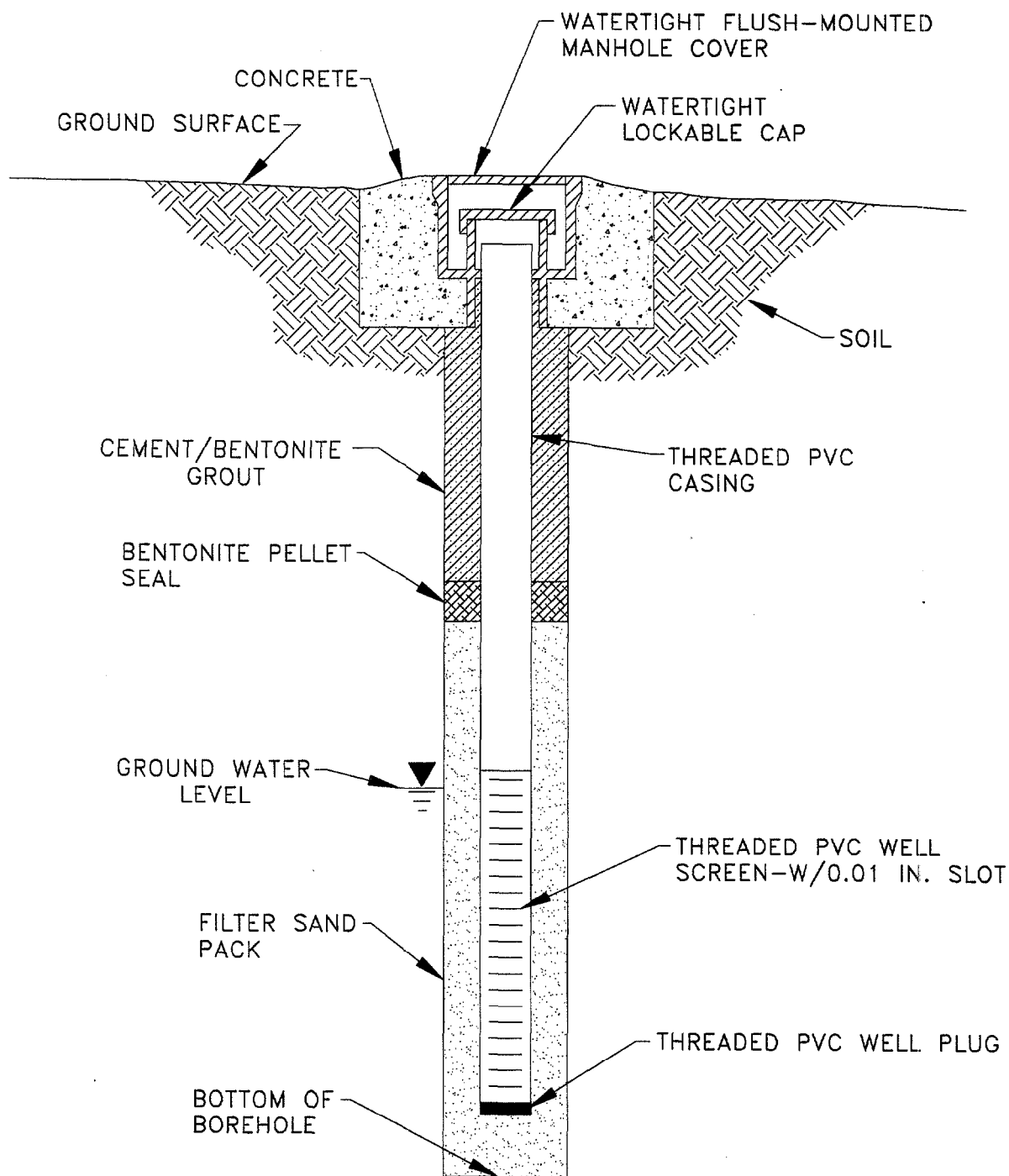
- - - - - INTERMITTENT DRAINAGE SWELL
- ~ ~ ~ ~ ~ TREE LINE
- GRAVEL ROAD
- PROPOSED SOIL SAMPLING LOCATION

SOURCE: BRENT A. LANIER R.L.S., JANUARY 1996.



**Baker**  
Baker Environmental, Inc.

FIGURE 4-1  
PROPOSED SAMPLING LOCATIONS  
SITE 84  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA



N.T.S.

**Baker**  
Baker Environmental, Inc.

FIGURE 6-1  
TYPICAL BELOW GRADE SHALLOW TYPE II GROUNDWATER  
MONITORING WELL CONSTRUCTION DIAGRAM  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO - 0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA

**APPENDIX A**  
**SOIL AND ROCK ACQUISITION**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
SOIL AND ROCK SAMPLE ACQUISITION**

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**Page 1 of 10  
SOP Number: F102  
Effective Date: 04/94**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Subsurface Soil Samples
5.1.1	Split-Barrel (Split-Spoon) Sampling
5.1.2	Thin-Wall (Shelby Tube) Sampling
5.1.3	Bucket (Hand) Auger Sampling
5.1.4	Direct Push Sampling
5.2	Surface Soil Samples
5.3	Rock Cores
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

**ATTACHMENT A -- ASTM D1586-84 STANDARD METHOD FOR PENETRATION TEST AND  
SPLIT-BARREL SAMPLING OF SOILS**

**ATTACHMENT B -- ASTM D1587-83 STANDARD PRACTICE FOR THIN-WALLED TUBE  
SAMPLING OF SOILS**

**ATTACHMENT C -- ASTM D2113-83 (1987) STANDARD PRACTICE FOR DIAMOND CORE  
DRILLING FOR SITE INVESTIGATION**

**ATTACHMENT D -- ASTM D6282-98 STANDARD GUIDE FOR DIRECT PUSH SOIL SAMPLING  
FOR ENVIRONMENTAL SITE CHARACTERIZATIONS**



## SOIL AND ROCK SAMPLE ACQUISITION

### 1.0 PURPOSE

The purpose of this procedure is to describe the handling of rock cores and subsurface soil samples collected during drilling operations. Surface soil sampling also is described.

### 2.0 SCOPE

The methods described in this SOP are applicable for the recovery of subsurface soil and rock samples acquired by coring operations or soil sampling techniques such as split-barrel sampling and thin-walled tube sampling. Procedures for the collection of surface soil samples also are discussed. This SOP does not discuss drilling techniques or well installation procedures. ASTM procedures for "Penetration Test and Split-Barrel Sampling of Soils," "Thin-Walled Tube Sampling of Soils," and "Diamond Core Drilling for Site Investigation" have been included as Attachments A through C, respectively.

### 3.0 DEFINITIONS

Thin-Walled Tube Sampler - A thin-walled metal tube (also called Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outer diameter (O.D.) and 18 to 54 inches length.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into unconsolidated materials using a drive weight mounted on the drilling string. A standard split-spoon sampler (used for performing Standard Penetration Tests) is two inches O.D. and 1-3/8-inches inner diameter (I.D.). This standard spoon is available in two common lengths providing either 20-inch or 26-inch internal longitudinal clearance for obtaining 18-inch or 24-inch long samples, respectively.

Grab Sample - An individual sample collected from a single location at a specific time or period of time generally not exceeding 15 minutes. Grab samples are associated with surface water, groundwater, wastewater, waste, contaminated surfaces, soil, and sediment sampling. Grab samples are typically used to characterize the media at a particular instant in time.

Composite Samples - A sample collected over time that typically consists of a series of discrete samples which are combined or "composited." Two types of composite samples are listed below:

- Areal Composite: A sample collected from individual grab samples collected on an areal or cross-sectional basis. Areal composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include sediment composites from quarter-point sampling of streams and soil samples from grid points.

- Vertical Composite: A sample collected from individual grab samples collected from a vertical cross section. Vertical composites shall be made up of equal volumes of grab samples. Each grab sample shall be collected in an identical manner. Examples include vertical profiles of soil/sediment columns, lakes and estuaries.

#### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that, where applicable, project-specific plans are in accordance with these procedures, or that other approved procedures are developed. Furthermore, the Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific sampling techniques and equipment to be used, and documenting these in accordance with the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Drilling Inspector - It is the responsibility of the drilling inspector to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The Drilling Inspector is responsible for the proper acquisition of rock cores and subsurface soil samples.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of samples.

#### 5.0 PROCEDURES

Subsurface soil and rock samples are used to characterize the three-dimensional subsurface stratigraphy. This characterization can indicate the potential for migration of contaminants from various sites. In addition, definition of the actual migration of contaminants can be obtained through chemical analysis of subsurface soil samples. Where the remedial activities may include in-situ treatment, or the excavation and removal of the contaminated soil, the depth and areal extent of contamination must be known as accurately as possible.

Surface soil samples serve to characterize the extent of surface contamination at various sites. These samples may be collected during initial site screening to determine gross contamination levels and levels of personal protection required as part of more intensive field sampling activities, to gather more detailed site data during design, or to determine the need for, or success of, cleanup actions.

Site construction activities may require that the engineering and physical properties of soil and rock be determined. Soil types, bearing strength, compressibility, permeability, plasticity, and moisture content are some of the geotechnical characteristics that may be determined by laboratory tests of soil samples. Rock quality, strength, stratigraphy, structure, etc. often are needed to design and construct deep foundations or remedial components.

## **5.1     Subsurface Soil Samples**

This section discusses four methods for collecting subsurface soil samples: (1) split-spoon sampling; (2) shelby tube sampling; (3) bucket auger sampling; and direct push sampling. All four methods yield samples suitable for laboratory analysis. Copies of the ASTM procedures for split-spoon sampling, shelby-tube sampling and direct push sampling are provided in Attachments A, B and C, respectively.

### **5.1.1   Split-Barrel (Split-Spoon) Sampling**

The following procedures are to be used for split-spoon, geotechnical soil sampling:

1.     Clean out the borehole to the desired sampling depth using equipment that will ensure that the material to be sampled is not disturbed by the operation.
2.     Side-discharge or bottom-discharge bits are permissible. The process of jetting through the sampler and then sampling when the desired depth is reached shall not be permitted. Where casing is used, it may not be driven below the sampling elevation.
3.     The two-inch O.D. split-barrel (not for geotech) sampler should be driven with blows from a 140-pound hammer falling 30 inches in accordance with ASTM D1586-84, Standard Penetration Test.
4.     Repeat this operation at intervals not longer than 5 feet in homogeneous strata, or as specified in the Sampling and Analysis Plan.
5.     Record on the Field Test Boring Record or field logbook the number of blows required to effect each six inches of penetration or fraction thereof. The first six inches is considered to be a seating drive. The sum of the number of blows required for the second and third six inches of penetration is termed the penetration resistance, N. If the sampler is driven less than 18 inches, the penetration resistance is that for the last one foot of penetration. (If less than one foot is penetrated, the logs shall state the number of blows and the fraction of one foot penetrated.) In cases where samples are driven 24 inches, the sum of second and third six-inch increments will be used to calculate the penetration resistance. (Refusal of the Standard Penetration Test will be noted as 50 blows over an interval equal to or less than 6 inches; the interval driven will be noted with the blow count.)
6.     Bring the sampler to the surface and remove both ends and one half of the split-spoon such that the soil recovered rests in the remaining half of the barrel. Describe carefully the recovery (length), composition, structure, consistency, color, condition, etc. of the recovered soil according to SOP F101; then put into jars without ramming. Jars with samples not taken for chemical analysis should be tightly closed, to prevent evaporation of the soil moisture. Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302). Protect samples against extreme temperature changes and breakage by placing them in appropriate cartons stored in a protected area.

In addition to collecting soils for geotechnical purposes, split-spoon sampling can be employed to obtain samples for environmental analytical analysis. The following procedures are to be used for split-spoon, environmental soil sampling:

1. Follow sample collection procedures 1 through 6 as outlined in Section 5.1.1.
2. After sample collection, remove the soil from the split-spoon sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.
3. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s).
4. Pack the samples for shipping (see SOP F301). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F302).
5. Decontaminate the split-spoon sample as described in SOP F501 and SOP F502. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

For obtaining composite soil samples (see Section 3.0), a slightly modified approach is employed. Each individual discrete soil sample from the desired sample interval will be placed into a stainless-steel, decontaminated bowl (or other appropriate container) prior to filling the laboratory sample containers. Special care should be taken to cover the bowl between samples with aluminum foil to minimize volatilization. Immediately after obtaining soils from the desired sampling interval, the sample to be analyzed for Volatile Organic Compounds (VOCs) should be collected. In the event that a composite sample is required, care should be taken to obtain a representative sampling of each sample interval. The remaining soils should be thoroughly mixed. Adequate mixing can be achieved by stirring in a circular fashion and occasionally turning the soils over. Once the remaining soils have been thoroughly combined, samples for analyses other than VOCs should be placed into the appropriate sampling containers.

### **5.1.2 Thin-Wall (Shelby Tube) Sampling**

When it is desired to take undisturbed samples of soil for physical laboratory testing, thin-walled seamless tube samplers (Shelby tubes) will be used. The following method applies:

1. Clean out the hole to the sampling elevation, being careful to minimize the chance for disturbance or contamination of the material to be sampled.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the hole shall not be allowed. Only side discharge bits are permitted.

3. Prior to inserting the tube sampler in the hole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out of the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. With the sampling tube resting on the bottom of the hole and the water level in the boring at the natural groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed further than the length provided for the soil sample. Allow a free space in the tube for cuttings and sludge.
5. After pushing the tube, the sample should sit 5 to 15 minutes prior to removal. Immediately before removal, the sample must be sheared by rotating the rods with a pipe wrench a minimum of two revolutions.
6. Upon removal of the sampler tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil, from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Newspaper or other types of filler must be placed in voids at either end of the sampler prior to sealing with wax. Place plastic caps on the ends of the sampler, tape them into place and then dip the ends in wax to seal them.
7. Affix labels to the tubes and record sample number, depth, penetration, and recovery length on the label. Mark the same information and "up" direction on the tube with indelible ink, and indicate the top of the sample. Complete chain-of-custody and other required forms (see SOP F302). Do not allow tubes to freeze, and store the samples vertically (with the same orientation they had in the ground, i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.
8. From soil removed from the ends of the tube, make a careful description using the methods presented in SOP F101.
9. When thin-wall tube samplers are used to collect soil for certain chemical analyses, it may be necessary to avoid using wax, newspaper, or other fillers.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Other appropriate devices can be used in conjunction with the tube samplers to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs and, therefore, their use should be weighed against the increased cost and the need for an undisturbed sample. In any case, if a sample cannot be obtained with a tube sampler, an attempt should be made with a split-spoon sampler at the same depth so that at least one sample can be obtained for classification purposes.

### 5.1.3 Bucket (Hand) Auger Sampling

Hand augering is the most common manual method used to collect subsurface samples. Typically, 4-inch auger buckets with cutting heads are pushed and twisted into the ground and removed as the buckets are filled. The auger holes are advanced one bucket at a time. The practical depth of investigation using a hand auger is related to the material being sampled. In sands, augering is usually easily accomplished, but the depth of investigation is controlled by the depth at which sands begin to cave. At this point, auger holes usually begin to collapse and cannot practically be advanced to lower depths, and further samples, if required, must be collected using some type of pushed or driven device. Hand augering may also become difficult in tight clays or cemented sands. At depths approaching 20 feet, torquing of hand auger extensions becomes so severe that in resistant materials powered methods must be used.

When a vertical sampling interval has been established, one auger bucket is used to advance the auger hole to the first desired sampling depth. If the sample at this location is to be a vertical composite of all intervals, the same bucket may be used to advance the hole, as well collect subsequent samples in the same hole. However, if discrete grab samples are to be collected to characterize each depth, a decontaminated bucket must be placed on the end of the auger extension immediately prior to collecting the next sample. The top several inches of soil should be removed from the bucket to minimize the chances of cross-contamination of the sample from fall-in of material from the upper portions of the hole. The bucket auger should be decontaminated between samples as outlined in SOP F502.

In addition to hand augering, powered augers can be used to advance a boring for subsurface soil collection. However, this type of equipment is technically a sampling aid and not a sampling device, and 20 to 25 feet is the typical lower depth range for this equipment. It is used to advance a hole to the required sample depth, at which point a hand auger is usually used to collect the sample.

### 5.1.4 Direct Push Sampling

Direct push sampling has become a widely used technique for collecting environmental samples of soil and groundwater. There are multiple sampling devices and different sized samplers used in direct push methods. Please refer to ASTM standards in attachment D. This is a general procedure for sampling and could change depending on work plan and type of sampling being done.

1. The sampler should be driven to desired depth for sample.
2. Bring the sampler to the surface and remove soil sleeve. Record all pertinent sampling information such as soil description, sample depth, sample number, sample location, and time of sample collection in the Field Test Boring Record or field logbook. In addition, label, tag, and number the sample bottle(s). Affix labels to the jar and complete Chain-of-Custody and other required sample data forms (see SOP F302).
3. After sample collection, remove the soil from the sampler. Prior to filling laboratory containers, the soil sample should be mixed thoroughly as possible to ensure that the sample is as representative as possible of the sample interval. Soil samples for volatile organic compounds should not be mixed. Further, sample containers for volatile organic

compounds analyses should be filled completely without head space remaining in the container to minimize volatilization.

4. Pack the samples for shipping (see SOP F301). Attach seal to the shipping package. Make sure that Chain-of-Custody Forms and Sample Request Forms are properly filled out and enclosed or attached (see SOP F302).
5. Decontaminate the sampler as described in SOP F501 and SOP F502. Replace disposable latex gloves between sample stations to prevent cross-contaminating samples.

## **5.2 Surface Soil Samples**

Surface soils are generally classified as soils between the ground surface and 6 to 12 inches below ground surface. For loosely packed surface soils, stainless steel (organic analyses) or plastic (inorganic analyses) scoops or trowels, can be used to collect representative samples. For densely packed soils or deeper soil samples, a hand or power soil auger may be used.

The following methods are to be used:

1. Use a soil auger for deep samples (greater than 12 inches) or a scoop or trowel for surface samples. Remove debris, rocks, twigs, and vegetation before collecting the sample.
2. Immediately transfer the sample to the appropriate sample container. Attach a label and identification tag. Record all required information in the field logbook (SOP F303) and on the sample log sheet, chain-of-custody record (SOP F302), and other required forms.
3. Classify and record a description of the sample, as discussed in SOP F101. Descriptions for surface soil samples should be recorded in the field logbook; descriptions for soil samples collected with power or hand augers shall be recorded on a Field Test Boring Record.
4. Store the sampling utensil in a plastic bag until decontamination or disposal. Use a new or freshly-decontaminated sampling utensil for each sample taken.
5. Pack and ship as described in SOP F301.
6. Mark the location with a numbered stake if possible and locate sample points on a sketch of the site or on a sketch in the field logbook.
7. When a representative composited sample is to be prepared (e.g., samples taken from a gridded area or from several different depths), it is best to composite individual samples in the laboratory where they can be more precisely composited on a weight or volume basis. If this is not possible, the individual samples (all of equal volume, i.e., the sample bottles should be full) should be placed in a stainless steel bucket (or other appropriate container), mixed thoroughly using a decontaminated stainless steel spatula or trowel, and a composite sample collected. In some cases, as delineated in project-specific sampling and analysis plans, laboratory compositing of the samples may be more appropriate than field



compositing. Samples to be analyzed for parameters sensitive to volatilization should be composited and placed into the appropriate sample bottles immediately upon collection.

### 5.3 Rock Cores

Once rock coring has been completed and the core recovered, the rock core must be carefully removed from the barrel, placed in a core tray (previously labeled "top" and "bottom" to avoid confusion), classified, and measured for percentage of recovery, as well as the rock quality designation (RQD) (see SOP F101). If split-barrels are used, the core may be measured and classified in the split barrel after opening and then transferred to a core box.

Each core shall be described and classified on a Field Test Boring Record using a uniform system as presented in SOP F101. If moisture content will be determined or if it is desirable to prevent drying (e.g., to prevent shrinkage of hydrated formations) or oxidation of the core, the core must be wrapped in plastic sleeves immediately after logging. Each plastic sleeve shall be labeled with indelible ink. The boring number, run number and the footage represented in each sleeve shall be included, as well as the top and bottom of the core run.

After sampling, rock cores must be placed in the sequence of recovery in wooden or plastic core boxes provided by the drilling contractor. Rock cores from different borings shall not be placed in the same core box. The core boxes should be constructed to accommodate 10 to 20 linear feet of core and should be constructed with hinged tops secured with screws, and a latch (usually a hook and eye) to keep the top securely fastened. Wood partitions shall be placed at the end of each core run and between rows. The depth from the surface of the boring to the top and bottom of the drill run and the run number shall be marked on the wooden partitions with indelible ink. The order of placing cores shall be the same in all core boxes. The top of each core obtained should be clearly and permanently marked on each box. The width of each row must be compatible with the core diameter to prevent lateral movement of the core in the box. Similarly, any empty space in a row shall be filled with an appropriate filler material or spacers to prevent longitudinal movement of the core in the box.

The inside and outside of the core-box lid shall be marked by indelible ink to show all pertinent data pertaining to the box's contents. At a minimum, the following information must be included:

- Project name
- Date
- Boring number
- Footage (depths)
- Run number(s)
- Recovery
- Rock Quality Designation (RQD)
- Box number (x of x)

It is also useful to draw a large diagram of the core in the box, on the inside of the box top. This provides more room for elevations, run numbers, recoveries, comments, etc., than could be entered on the upper edges of partitions or spaces in the core box.

For easy retrieval when core boxes are stacked, the sides and ends of the box should also be labeled and include project name, boring number, top and bottom depths of core and box number.

Due to the weight of the core, a filled core box should always be handled by two people. Core boxes stored on site should be protected from the weather. The core boxes should be removed from the site in a careful manner as soon as possible. Exposure to extreme heat or cold should be avoided whenever possible. Arrangements should be made to dispose of or return the core samples to the client for completion of the project.

## 6.0 QUALITY ASSURANCE RECORDS

Where applicable, Field Test Boring Records and Test Boring Records will serve as the quality assurance records for subsurface soil samples, rock cores and near surface soil samples collected with a hand or power auger. Observations shall be recorded in the Field Logbook as described in SOP F303. Chain-of-Custody records shall be completed for samples collected for laboratory analysis as described in SOP F101 and SOP F302.

## 7.0 REFERENCES

1. American Society for Testing and Materials, 1987. Standard Method for Penetration Test and Split-Barrel Sampling of Soils. ASTM Method D1586-84, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1987. Standard Practice for Thin-Walled Tube Sampling of Soils. Method D1587-83, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
3. American Society for Testing and Materials, 1987. Standard Practice for Diamond Core Drilling for Site Investigation. Method D2113-83 (1987), Annual Book of Standards ASTM, Philadelphia, Pennsylvania.
4. U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D1586-84  
STANDARD METHOD FOR PENETRATION TEST AND  
SPLIT-BARREL SAMPLING OF SOILS**



## Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1586; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

<sup>1</sup>NOTE—Editorial changes were made throughout October 1992.

### 1. Scope

1.1 This test method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D2487 Test Method for Classification of Soils for Engineering Purposes<sup>2</sup>

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>

D4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>

D4633 Test Method for Stress Wave Energy Measurement for Dynamic Penetrometer Testing Systems<sup>2</sup>

### 3. Terminology

#### 3.1 Descriptions of Terms Specific to This Standard

3.1.1 *anvil*—that portion of the drive-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.1.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.1.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.1.4 *drive-weight assembly*—a device consisting of the

hammer, hammer fall guide, the anvil, and any hammer drop system.

3.1.5 *hammer*—that portion of the drive-weight assembly consisting of the  $140 \pm 2$  lb ( $63.5 \pm 1$  kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.1.6 *hammer drop system*—that portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.1.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.1.8 *N-value*—the blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in. (150 to 450 mm) (see 7.3).

3.1.9  $\Delta N$ —the number of blows obtained from each of the 6-in. (150-mm) intervals of sampler penetration (see 7.3).

3.1.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the operator's rope slackening to drop the hammer, divided by  $360^\circ$  (see Fig. 1).

3.1.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.1.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

### 4. Significance and Use

4.1 This test method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This test method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N-value*, and the engineering behavior of earthworks and foundations are available.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be

<sup>1</sup> This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

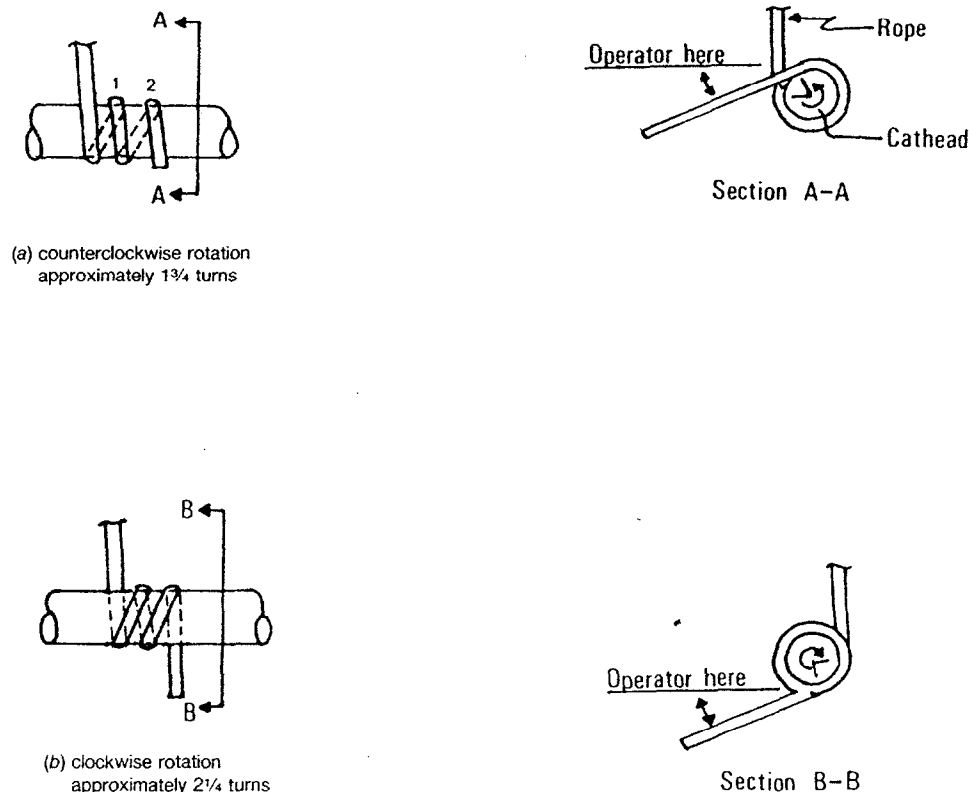


FIG. 1 Definitions of the Number of Rope Turns and the Angle for (a) Counterclockwise Rotation and (b) Clockwise Rotation of the Cathead

suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers*, with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers*, less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sampler to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of  $1\frac{1}{8}$  in. (41.2 mm) and an inside diameter of  $1\frac{1}{8}$  in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the  $N$ -values to depths of at least 1 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replaced or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of  $1\frac{3}{8}$  in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

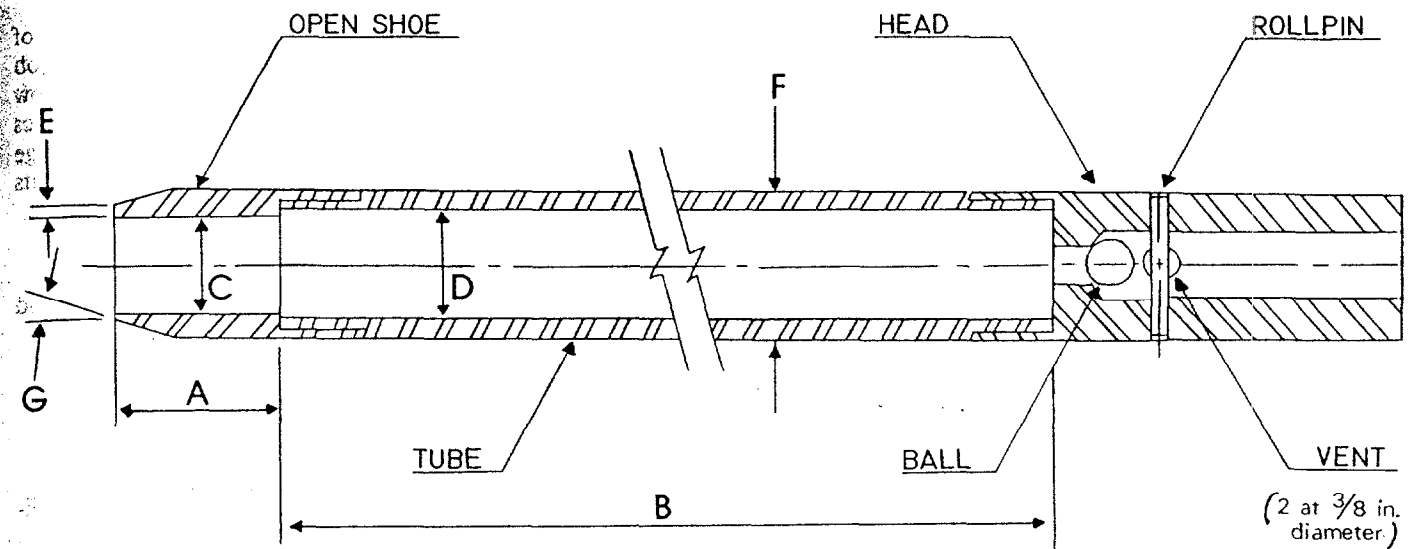
NOTE 2—Both theory and available test data suggest that  $N$ -values may increase between 10 to 30 % when liners are used.

#### 5.4 Drive-Weight Assembly:

5.4.1 *Hammer and Anvil*—The hammer shall weigh  $140 \pm 2$  lb ( $63.5 \pm 1$  kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an unimpeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used providing the lifting apparatus will not cause penetration



- A = 1.0 to 2.0 in. (25 to 50 mm)  
 B = 18.0 to 30.0 in. (0.457 to 0.762 m)  
 C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)  
 D = 1.50 ± 0.05 - 0.00 in. (38.1 ± 1.3 - 0.0 mm)  
 E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)  
 F = 2.00 ± 0.05 - 0.00 in. (50.8 ± 1.3 - 0.0 mm)  
 G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

the sampler while re-engaging and lifting the hammer.

**5.5 Accessory Equipment**—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

## 6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 m) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

- 6.2.1 Open-hole rotary drilling method.
- 6.2.2 Continuous flight hollow-stem auger method.
- 6.2.3 Wash boring method.
- 6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing

may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

## 7. Sampling and Testing Procedure.

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-

kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance," or the "*N*-value." If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb (63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop  $30 \pm 1.0$  in. (0.76 m  $\pm$  25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than  $2\frac{1}{4}$  rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either  $1\frac{3}{4}$  or  $2\frac{1}{4}$  rope turns, depending upon whether or not the rope comes off the top ( $1\frac{3}{4}$  turns) or the bottom ( $2\frac{1}{4}$  turns) of the cathead. It is generally known and accepted that  $2\frac{3}{4}$  or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent

stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

## 8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job,

8.1.2 Names of crew,

8.1.3 Type and make of drilling machine,

8.1.4 Weather conditions,

8.1.5 Date and time of start and finish of boring,

8.1.6 Boring number and location (station and coordinates, if available and applicable),

8.1.7 Surface elevation, if available,

8.1.8 Method of advancing and cleaning the boring,

8.1.9 Method of keeping boring open,

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made,

8.1.11 Location of strata changes,

8.1.12 Size of casing, depth of cased portion of boring,

8.1.13 Equipment and method of driving sampler,

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners),

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number,

8.2.2 Description of soil,

8.2.3 Strata changes within sample,

8.2.4 Sampler penetration and recovery lengths, and

8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

## 9. Precision and Bias

9.1 *Precision*—A valid estimate of test precision has not been determined because it is too costly to conduct the necessary inter-laboratory (field) tests. Subcommittee D18.02 welcomes proposals to allow development of a valid precision statement.

9.2 *Bias*—Because there is no reference material for this test method, there can be no bias statement.

9.3 Variations in *N*-values of 100 % or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, *N*-values in the same soil can be reproduced with a coefficient of variation of about 10 %.

9.4 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.



9.5 The variability in  $N$ -values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting  $N$  on the basis of comparative energies. A method for energy measurement and  $N$ -value

adjustment is given in Test Method D 4633.

## 10. Keywords

10.1 blow count; in-situ test; penetration resistance; split-barrel sampling; standard penetration test

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.*

**ATTACHMENT B**

**ASTM D1587-83**

**STANDARD PRACTICE FOR THIN-WALLED TUBE SAMPLING OF SOILS**



## Standard Practice for Thin-Walled Tube Sampling of Soils<sup>1</sup>

This standard is issued under the fixed designation D 1587; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.*

### 1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Denison or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>

D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>

D 4220 Practices for Preserving and Transporting Soil Samples<sup>2</sup>

### 3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

### 4. Significance and Use

4.1 This practice, or Practice D 3550, is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

### 5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole; that does not disturb the soil to be sampled; and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For

hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as shown in Fig. 1. They should have an outside diameter of 2 to 5 in. and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1 % or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled. See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of time as well as interaction between the sample and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and others. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

### 6. Procedure

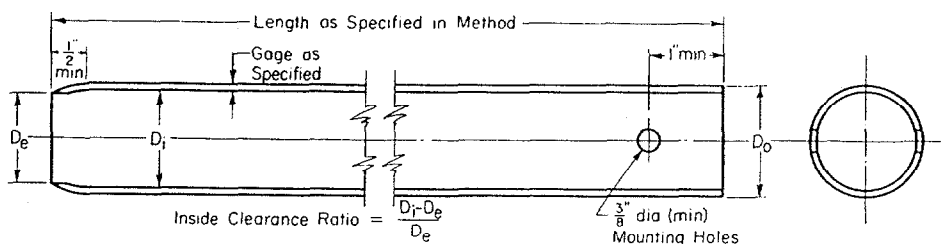
6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used, with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.08.



- NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.  
 NOTE 2—Minimum of four mounting holes spaced at 90° for samplers 4 in. and larger.  
 NOTE 3—Tube held with hardened screws.  
 NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio criteria accepted for "undisturbed samples." Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in.	mm
3/8	6.77
1/2	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

TABLE 1 Suitable Thin-Walled Steel Sample Tubes<sup>A</sup>

Outside diameter:			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

<sup>A</sup> The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1 <sup>A</sup> Tolerances, in.			
Size Outside Diameter	2	3	5
Outside diameter	+0.007 -0.000	+0.010 -0.000	+0.015 -0.000
Inside diameter	+0.000 -0.007	+0.000 -0.010	+0.000 -0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

<sup>A</sup> Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D., or O.D. and Wall, or I.D. and Wall.

possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed

5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven or Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

## 7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice D 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the

markings or labels are adequate to survive transportation and storage.

## 8. Report

8.1 The appropriate information is required as follows:

- 8.1.1 Name and location of the project,
- 8.1.2 Boring number and precise location on project,
- 8.1.3 Surface elevation or reference to a datum,
- 8.1.4 Date and time of boring—start and finish,
- 8.1.5 Depth to top of sample and number of sample,
- 8.1.6 Description of sampler: size, type of metal, type of coating,
- 8.1.7 Method of sampler insertion: push or drive,

8.1.8 Method of drilling, size of hole, casing, and drilling fluid used,

8.1.9 Depth to groundwater level: date and time measured,

8.1.10 Any possible current or tidal effect on water level,

8.1.11 Soil description in accordance with Practice D 2488,

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

## 9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103. known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.*

**ATTACHMENT C**

**ASTM D2113-83 (1987)  
STANDARD PRACTICE FOR DIAMOND CORE DRILLING FOR  
SITE INVESTIGATION**



## Standard Practice for Diamond Core Drilling for Site Investigation<sup>1</sup>

This standard is issued under the fixed designation D 2113; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense*

<sup>1</sup> NOTE—Editorial changes were made and Section 9 added editorially in September 1993.

### 1. Scope

1.1 This practice describes equipment and procedures for diamond core drilling to secure core samples of rock and some soils that are too hard to sample by soil-sampling methods. This method is described in the context of obtaining data for foundation design and geotechnical engineering purposes rather than for mineral and mining exploration.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>
- D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>

### 3. Significance and Use

3.1 This practice is used to obtain core specimens of superior quality that reflect the in-situ conditions of the material and structure and which are suitable for standard physical-properties tests and structural-integrity determination.

### 4. Apparatus

4.1 *Drilling Machine*, capable of providing rotation, feed, and retraction by hydraulic or mechanical means to the drill rods.

4.2 *Fluid Pump or Air Compressor*, capable of delivering sufficient volume and pressure for the diameter and depth of hole to be drilled.

4.3 *Core barrels*, as required:

4.3.1 *Single Tube Type, WG Design*, consisting of a hollow steel tube, with a head at one end threaded for drill rod, and a threaded connection for a reaming shell and core

bit at the other end. A core lifter, or retainer located within the core bit is normal, but may be omitted at the discretion of the geologist or engineer.

4.3.2 *Double Tube, Swivel-Type, WG Design*—An assembly of two concentric steel tubes joined and supported at the upper end by means of a ball or roller-bearing swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube. The upper end of the outer tube, or removable head, is threaded for drill rod. A threaded connection is provided on the lower end of the outer tube for a reaming shell and core bit. A core lifter located within the core bit is normal but may be omitted at the discretion of the geologist or engineer.

4.3.3 *Double-Tube, Swivel-Type, WT Design*, is essentially the same as the double tube, swivel-type, WG design, except that the WT design has thinner tube walls, a reduced annular area between the tubes, and takes a larger core from the same diameter bore hole. The core lifter is located within the core bit.

4.3.4 *Double Tube, Swivel Type, WM Design*, is similar to the double tube, swivel-type, WG design, except that the inner tube is threaded at its lower end to receive a core lifter case that effectively extends the inner tube well into the core bit, thus minimizing exposure of the core to the drilling fluid. A core lifter is contained within the core lifter case on the inner tube.

4.3.5 *Double Tube Swivel-Type, Large-Diameter Design*, is similar to the double tube, swivel-type, WM design, with the addition of a ball valve, to control fluid flow, in all three available sizes and the addition of a sludge barrel, to catch heavy cuttings, on the two larger sizes. The large-diameter design double tube, swivel-type, core barrels are available in three core per hole sizes as follows: 2¾ in. (69.85 mm) by 3¾ in. (98.43 mm), 4 in. (101.6 mm) by 5½ in. (139.7 mm), and 6 in. (152.4 mm) by 7¾ in. (196.85 mm). Their use is generally reserved for very detailed investigative work or where other methods do not yield adequate recovery.

4.3.6 *Double Tube, Swivel-Type, Retrievable Inner-Tube Method*, in which the core-laden inner-tube assembly is retrieved to the surface and an empty inner-tube assembly returned to the face of the borehole through the matching, large-bore drill rods without need for withdrawal and replacement of the drill rods in the borehole. The inner-tube assembly consists of an inner tube with removable core lifter case and core lifter at one end and a removable inner-tube head, swivel bearing, suspension adjustment, and latching

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.02 on Sampling and Related Field Testing for Soil Investigations.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.08.

device with release mechanism on the opposite end. The inner-tube latching device locks into a complementary recess in the wall of the outer tube such that the outer tube may be rotated without causing rotation of the inner tube and such that the latch may be actuated and the inner-tube assembly transported by appropriate surface control. The outer tube is threaded for the matching, large-bore drill rod and internally configured to receive the inner-tube latching device at one end and threaded for a reaming shell and bit, or bit only, at the other end.

**4.4 Longitudinally Split Inner Tubes**—As opposed to conventional cylindrical inner tubes, allow inspection of, and access to, the core by simply removing one of the two halves. They are not standardized but are available for most core barrels including many of the retrievable inner-tube types.

**4.5 Core Bits**—Core bits shall be surface set with diamonds, impregnated with small diamond particles, inserted with tungsten carbide slugs, or strips, hard-faced with various hard surfacing materials or furnished in saw-tooth form, all as appropriate to the formation being cored and with concurrence of the geologist or engineer. Bit matrix material, crown shape, water-way type, location and number of water ways, diamond size and carat weight, and bit facing materials shall be for general purpose use unless otherwise approved by the geologist or engineer. Nominal size of some bits is shown in Table 1.

NOTE 1—Size designation (letter symbols) used throughout the text and in Tables 1, 2, and 3 are those standardized by the Diamond Core Drill Manufacturers' Assoc. (DCDMA). Inch dimensions in the tables have been rounded to the nearest hundredth of an inch.

**4.6 Reaming Shells**, shall be surface set with diamonds,

**TABLE 1 Core Bit Sizes**

Size Designation	Outside Diameter		Inside Diameter	
	in.	mm	in.	mm
RWT	1.16	29.5	0.375	18.7
EWT	1.47	37.3	0.905	22.9
EWG, EWM	1.47	37.3	0.845	21.4
AWT	1.88	47.6	1.281	32.5
AWG, AWM	1.88	47.6	1.185	30.0
BWT	2.35	59.5	1.750	44.5
BWG, BWM	2.35	59.5	1.655	42.0
NWT	2.97	75.3	2.313	58.7
NWG, NWM	2.97	75.3	2.155	54.7
2¾ × 3⅞	3.84	97.5	2.69	68.3
HWT	3.89	98.8	3.187	80.9
HWG, . . .	3.89	98.8	3.000	76.2
4 × 5½	5.44	138.0	3.97	100.8
6 × 7¾	7.66	194.4	5.97	151.6

impregnated with small diamond particles, inserted with tungsten carbide strips or slugs, hard faced with various types of hard surfacing materials, or furnished blank, all as appropriate to the formation being cored.

**4.7 Core Lifters**—Core lifters of the split-ring type, either plain or hard-faced, shall be furnished and maintained, along with core-lifter cases or inner-tube extensions or inner-tube shoes, in good condition. Basket or finger-type lifters, together with any necessary adapters, shall be on the job and available for use with each core barrel if so directed by the geologist or engineer.

**4.8 Casings:**

**4.8.1 Drive Pipe or Drive Casing**, shall be standard weight (schedule 40), extra-heavy (schedule 80), double extra-heavy (schedule 160) pipe or W-design flush-joint casing as required by the nature of the overburden or the placement method. Drive pipe or W-design casing shall be of sufficient diameter to pass the largest core barrel to be used, and it shall be driven to bed rock or to firm seating at an elevation below water-sensitive formation. A hardened drive shoe is to be used as a cutting edge and thread protection device on the bottom of the drive pipe or casing. The drive shoe inside diameter shall be large enough to pass the tools intended for use, and the shoe and pipe or casing shall be free from burrs or obstructions.

**4.8.2 Casing**—When necessary to case through formations already penetrated by the borehole or when no drive casing has been set, auxiliary casing shall be provided to fit inside the borehole to allow use of the next smaller core barrel. Standard sizes of telescoping casing are shown in Table 2. Casing bits have an obstruction in their interior and will not pass the next smaller casing size. Use a casing shoe if additional telescoping is anticipated.

**4.8.3 Casing Liner**—Plastic pipe or sheet-metal pipe may be used to line an existing large-diameter casing. Liners, so used, should not be driven, and care should be taken to maintain true alignment throughout the length of the liner.

**4.8.4 Hollow Stem Auger**—Hollow stem auger may be used as casing for coring.

**4.9 Drill Rods:**

**4.9.1 Drill Rods of Tubular Steel Construction** are normally used to transmit feed, rotation, and retraction forces from the drilling machine to the core barrel. Drill-rod sizes that are presently standardized are shown in Table 3.

**4.9.2 Large bore drill rods** used with retrievable inner-tube core barrels are not standardized. Drill rods used with retrievable inner-tube core barrels should be those manufac-

**TABLE 2 Casing Sizes**

Size Designation	Outside Diameter		Inside Diameter		Threads per in.	Will Fit Hole Drilled with Core Bit Size
	in.	mm	in.	mm		
RW	1.144	36.5	1.19	30.1	5	EWG, EWG, EWM
EW	1.81	46.0	1.50	38.1	4	AWT, AWG, AWM
AW	2.25	57.1	1.91	48.4	4	BWT, BWG, BWM
BW	2.88	73.0	2.38	60.3	4	NWT, NWG, NWM
NW	3.50	88.9	3.00	76.2	4	HWT, HWG
HW	4.50	114.3	4.00	101.6	4	4 × 5½
PW	5.50	139.7	5.00	127.0	3	6 × 7¾
SW	6.63	168.2	6.00	152.4	3	6 × 7¾
UW	7.63	193.6	7.00	177.8	2	...
ZW	8.63	219.0	8.00	203.2	2	...



**TABLE 3 Drill Rods**

Size Designation	Rod and Coupling Outside Diameter		Rod Inside Diameter		Coupling Bore, Threads		
	in.	mm	in.	mm	in.	mm	per in.
RW	1.09	27.7	0.72	18.2	0.41	10.3	4
EW	1.38	34.9	1.00	25.4	0.44	11.1	3
AW	1.72	43.6	1.34	34.1	0.63	15.8	3
BW	2.13	53.9	1.75	44.4	0.75	19.0	3
NW	2.63	66.6	2.25	57.1	1.38	34.9	3
HW	3.50	88.9	3.06	77.7	2.38	60.3	3

tured by the core-barrel manufacturer specifically for the core barrel.

4.9.3 *Composite Drill Rods* are specifically constructed from two or more materials intended to provide specific properties such as light weight or electrical nonconductivity.

4.9.4 *Nonmagnetic Drill Rods* are manufactured of nonferrous materials such as aluminum or brass and are used primarily for hole survey work. Some nonmagnetic rods have left-hand threads in order to further their value in survey work. No standard exists for nonmagnetic rods.

4.10 *Auxiliary Equipment*, shall be furnished as required by the work and shall include: roller rock bits, drag bits, chopping bits, boulder busters, fishtail bits, pipe wrenches, core barrel wrenches, lubrication equipment, core boxes, and marking devices. Other recommended equipment includes: core splitter, rod wicking, pump-out tools or extruders, and hand sieve or strainer.

## 5. Transportation and Storage of Core Containers

5.1 *Core Boxes*, shall be constructed of wood or other durable material for the protection and storage of cores while enroute from the drill site to the laboratory or other processing point. All core boxes shall be provided with longitudinal separators and recovered cores shall be laid out as a book would read, from left to right and top to bottom, within the longitudinal separators. Spacer blocks or plugs shall be marked and inserted into the core column within the separators to indicate the beginning of each coring run. The beginning point of storage in each core box is the upper left-hand corner. The upper left-hand corner of a hinged core box is the left corner when the hinge is on the far side of the box and the box is right-side up. All hinged core boxes must be permanently marked on the outside to indicate the top and the bottom. All other core boxes must be permanently marked on the outside to indicate the top and the bottom and additionally, must be permanently marked internally to indicate the upper-left corner of the bottom with the letters UL or a splotch of red paint not less than 1 in.<sup>2</sup> Lid or cover fitting(s) for core boxes must be of such quality as to ensure against mix up of the core in the event of impact or upsetting of the core box during transportation.

5.2 Transportation of cores from the drill site to the laboratory or other processing point shall be in durable core boxes so padded or suspended as to be isolated from shock or impact transmitted to the transporter by rough terrain or careless operation.

5.3 Storage of cores, after initial testing or inspection at the laboratory or other processing point, may be in cardboard or similar less costly boxes provided all layout and marking requirements as specified in 5.1 are followed. Additional spacer blocks or plugs shall be added if necessary

at time of storage to explain missing core. Cores shall be stored for a period of time specified by the engineer but should not normally be discarded prior to completion of the project for which they were taken.

## 6. Procedure

6.1 Use core-drilling procedures when formations are encountered that are too hard to be sampled by soil-sampling methods. A 1-in. (25.4-mm) or less penetration for 50 blows in accordance with Method D 1586 or other criteria established by the geologist or engineer, shall indicate that soil-sampling methods are not applicable.

6.1.1 Seat the casing on bedrock or in a firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the surface of the rock or hard formation at the bottom of the casing when necessary, using the appropriate bits. Casing may be omitted if the borehole will stand open without the casing.

6.1.2 Begin the core drilling using an N-size double-tube swivel-type core barrel or other size or type approved by the engineer. Continue core drilling until core blockage occurs or until the net length of the core barrel has been drilled in. Remove the core barrel from the hole and disassemble it as necessary to remove the core. Reassemble the core barrel and return it to the hole. Resume coring.

6.1.3 Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box as described in 5.1. Continue boxing core with appropriate markings, spacers, and blocks as described in 5.1. Wrap soft or friable cores or those which change materially upon drying in plastic film or seal in wax, or both, when such treatment is required by the engineer. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core which might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.

6.1.4 Stop the core drilling when soft materials are encountered that produce less than 50 % recovery. If necessary, secure samples of soft materials in accordance with the procedures described in Method D 1586, Practice D 1587, or Practice D 3550, or by any other method acceptable to the geologist or engineer. Resume diamond core drilling when refusal materials as described in 6.1 are again encountered.

6.2 Subsurface structure, including the dip of strata, the occurrence of seams, fissures, cavities, and broken areas are among the most important items to be detected and described. Take special care to obtain and record information about these features. If conditions prevent the continued advance of the core drilling, the hole should be cemented and redrilled, or reamed and cased, or cased and advanced

with the next smaller-size core barrel, as required by the geologist or engineer.

6.3 Drilling mud or grouting techniques must be approved by the geologist or engineer prior to their use in the borehole.

#### 6.4 *Compatibility of Equipment:*

6.4.1 Whenever possible, core barrels and drill rods should be selected from the same letter-size designation to ensure maximum efficiency. See Tables 1 and 3.

6.4.2 Never use a combination of pump, drill rod, and core barrel that yields a clear-water up-hole velocity of less than 120 ft/min.

6.4.3 Never use a combination of air compressor, drill rod, and core barrel that yields a clear-air up-hole velocity of less than 3000 ft/min.

### 7. Boring Log

7.1 The boring log shall include the following:

7.1.1 Project identification, boring number, location, date boring began, date boring completed, and driller's name.

7.1.2 Elevation of the ground surface.

7.1.3 Elevation of or depth to ground water and raising or lowering of level including the dates and the times measured.

7.1.4 Elevations or depths at which drilling fluid return was lost.

7.1.5 Size, type, and design of core barrel used. Size, type, and set of core bit and reaming shell used. Size, type, and length of all casing used. Description of any movements of the casing.

7.1.6 Length of each core run and the length or percentage, or both, of the core recovered.

7.1.7 Geologist's or engineer's description of the formation recovered in each run.

7.1.8 Driller's description, if no engineer or geologist is present, of the formation recovered in each run.

7.1.9 Subsurface structure description, including dip of strata and jointing, cavities, fissures, and any other observations made by the geologist or engineer that could yield information regarding the formation.

7.1.10 Depth, thickness, and apparent nature of the filling of each cavity or soft seam encountered, including opinions gained from the feel or appearance of the inside of the inner tube when core is lost. Record opinions as such.

7.1.11 Any change in the character of the drilling fluid or drilling fluid return.

7.1.12 Tidal and current information when the borehole is sufficiently close to a body of water to be affected.

7.1.13 Drilling time in minutes per foot and bit pressure in pound-force per square inch gage when applicable.

7.1.14 Notations of character of drilling, that is, soft, slow, easy, smooth, etc.

### 8. Precision and Bias

8.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

NOTE 2—Inclusion of the following tables and use of letter symbols in the foregoing text is not intended to limit the practice to use of DCDMA tools. The table and text references are included as a convenience to the user since the vast majority of tools in use do meet DCDMA dimensional standards. Similar equipment of approximately equal size on the metric standard system is acceptable unless otherwise stipulated by the engineer or geologist.

### 9. Keywords

9.1 borehole; coring; rock; subsurface investigation

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**ATTACHMENT D**

**ASTM D6282-98  
STANDARD GUIDE FOR DIRECT PUSH SOIL SAMPLING  
FOR ENVIRONMENTAL SITE CHARACTERIZATIONS**



## Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations<sup>1</sup>

This standard is issued under the fixed designation D 6282; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This guide addresses direct push soil samplers, which also may be driven into the ground from the surface or through prebored holes. The samplers can be continuous or discrete interval units. Samplers are advanced by a combination of static push, or impacts from hammers, or vibratory methods, or a combination thereof, to the depth of interest. The guide does not cover open chambered samplers operated by hand such as augers, agricultural samplers operated at shallow depths, or side wall samplers. This guide does not address single sampling events in the immediate base of the drill hole using rotary drilling equipment with incremental drill hole excavation. Other sampling standards, such as Test Methods D 1586 and D 1587 and Practice D 3550 apply to rotary drilling activities. This guide does not address advancement of sampler barrel systems with methods that employ cuttings removal as the sampler is advanced. Other drilling and sampling methods may apply for samples needed for engineering and construction applications.

1.2 Guidance on preservation and transport of samples, as given in Guide D 4220, may or may not apply. Samples for chemical analysis often must be subsampled and preserved for chemical analysis using special techniques. Practice D 3694 provides information on some of the special techniques required. Additional information on environmental sample preservation and transportation is available in other references (1, 2).<sup>2</sup> Samples for classification may be preserved using procedures similar to Class A. In most cases, a direct push sample is considered as Class B in Practice D 4220 but is protected, representative, and suitable for chemical analysis. The samples taken with this practice do not usually produce Class C and D (with exception of thin wall samples of standard size) samples for testing for engineering properties, such as shear strength and compressibility. Guide D 4700 has some information on mechanical soil sampling devices similar to direct push techniques, however, it does not address most direct push sampling methods. If sampling is for chemical evaluation in the Vadose Zone, consult Guide D 4700 for any special considerations.

1.3 Field methods described in this guide, include the use of discreet and continuous sampling tools, split and solid barrel samplers and thin walled tubes with or without fixed piston style apparatus.

1.4 Insertion methods described include static push, impact, percussion, other vibratory/sonic driving, and combinations of these methods using direct push equipment adapted to drilling rigs, cone penetrometer units, and specially designed percussion/direct push combination machines. Hammers providing the force for insertion include drop style, hydraulically, activated, air activated and mechanical lift devices.

1.5 Direct push soil sampling is limited to soils and unconsolidated materials that can be penetrated with the available equipment. The ability to penetrate strata is based on hammer energy, carrying vehicle weight, compactness of soil, and consistency of soil. Penetration may be limited or damage to samplers and conveying devices can occur in certain subsurface conditions, some of which are discussed in 5.5. Successful sample recovery also may be limited by the ability to retrieve tools from the borehole. Sufficient retract force must be available when attempting difficult or deep investigations.

1.6 This guide does not address the installation of any temporary or permanent soil, ground water, vapor monitoring, or remediation devices.

1.7 The practicing of direct push techniques may be controlled by local regulations governing subsurface penetration. Certification, or licensing requirements, or both, may need to be considered in establishing criteria for field activities.

1.8 The values stated in SI units are to be regarded as standard; however, dimensions used in the drilling industry are given in inch-pound units by convention. Inch-pound units are used where necessary in this guide.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of*

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigation.

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<sup>2</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.

a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 420 Guide to Site Characterization for Engineering, Design and Construction Purposes<sup>3</sup>
- D 653 Terminology Relating to Soil, Rock and Contained Fluids<sup>3</sup>
- D 1452 Practice for Soil Investigation and Sampling by Auger Boring<sup>3</sup>
- D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils<sup>3</sup>
- D 1587 Practice for Thin-Wall Tube Sampling of Soils<sup>3</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Method)<sup>3</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>3</sup>
- D 3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents<sup>4</sup>
- D 4220 Practices for Preserving and Transporting Soil Samples<sup>3</sup>
- D 4700 Guide for Soil Sampling from the Vadose Zone<sup>3</sup>
- D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitor Well (Observation Well)<sup>3</sup>
- D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites<sup>5</sup>
- D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers<sup>5</sup>
- D 5299 Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities<sup>5</sup>
- D 5314 Guide for Soil Gas Sampling in the Vadose Zone<sup>5</sup>
- D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock<sup>5</sup>
- D 5730 Guide to Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water<sup>5</sup>
- D 5778 Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils<sup>5</sup>
- D 5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices<sup>5</sup>
- D 5784 Guide for Use of Hollow-stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality and Monitoring Devices<sup>5</sup>
- D 6001 Guide for Direct-Push Water Sampling for Geoenvironmental Investigations<sup>5</sup>

## 3. Terminology

3.1 *Definitions*—General definitions for terminology used in this guide are in accordance with Terminology D 653.

Definitions for terms related to direct push water sampling for geoenvironmental investigations are in accordance with Guide D 6001.

3.1.1 *assembly length, n*—length of sampler body and riser pipes.

3.1.2 *borehole, n*—a hole of circular cross-section made in soil or rock.

3.1.3 *casing, n*—pipe furnished in sections with either threaded connections or bevelled edges to be field-welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, or to isolate the interval being monitored, or combination thereof.

3.1.4 *caving/sloughing, n*—the inflow of unconsolidated material into an unsupported borehole that occurs when the borehole walls lose their cohesive strength.

3.1.5 *decontamination, n*—the process of removing undesirable physical or chemical constituents, or both, from equipment to reduce the potential for cross-contamination.

3.1.6 *direct push sampling, n*—sampling devices that are advanced into the soil to be sampled without drilling or borehole excavation.

3.1.7 *extension rod, n*—hollow steel rod, threaded, in various lengths, used to advance and remove samplers and other devices during direct pushing boring. Also known as *drive rod*. In some applications, small diameter solid extension rods are used through hollow drive rods to activate closed samples at depth.

3.1.8 *incremental drilling and sampling, n*—insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling often is needed to penetrate harder or deeper formations.

3.1.9 *percussion driving, n*—insertion method where rapid hammer impacts are performed to advance the sampling device. The percussion normally is accompanied with the application of a static down-force.

3.1.10 *push depth, n*—the depth below a ground surface datum to which the lower end, or tip, of the direct-push sampling device is inserted.

3.1.11 *sample interval, n*—defined zone within a subsurface strata from which a sample is gathered.

3.1.12 *sample recovery, n*—the length of material recovered divided by the length of sampler advancement and stated as a percentage.

3.1.13 *soil core, n*—cylindrical shaped specimen of sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks and which may or may not contain organic matter recovered from a soil sampler.

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *closed barrel sampler, n*—a sampling device with a piston or other secured device that is held to block the movement of material into the barrel until the blocking device is removed or released. Liners are required in closed barrel samplers. Also may be referred to as a *protected type sampler*.

3.2.2 *impact heads/drive heads, n*—pieces or assemblies that fit to top of the above ground portion of the direct push tool assembly to receive the impact of the hammering device transfer the impact energy to sampler extensions.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.08.

<sup>4</sup> Annual Book of ASTM Standards, Vol 11.02.

<sup>5</sup> Annual Book of ASTM Standards, Vol 04.09.

3.2.3 *open barrel sampler, n*—sampling barrel with open end allowing material to enter at any time or depth. Also may be referred to as an *unprotected type sampler*.

3.2.4 *piston lock, n*—device to lock the sampler piston in place to prevent any entry of a foreign substance into the sampler chamber prior to sampling.

3.2.5 *single tube system, n*—a system whereby single extension/drive rods with samplers attached are advanced into the subsurface strata to collect a soil sample.

3.2.6 *solid barrel sampler, n*—a soil sampling device consisting of a continuous or segmented tube with a wall thickness sufficient to withstand the forces necessary to penetrate the strata desired and gather a sample. A cutting shoe and a connecting head are attached to the barrel.

3.2.7 *split barrel sampler, n*—a soil sampling device consisting of the two half circle tubes manufactured to matching alignment, held together on one end by a shoe and on the other by a connecting head.

3.2.8 *two tube systems, n*—a system whereby inner and outer tubes are advanced simultaneously into the subsurface strata to collect a soil sample. The outer tube is used for borehole stabilization. The inner tube for sampler recovery and insertion.

#### 4. Summary of Guide

4.1 Direct push soil sampling consists of advancing a sampling device into subsurface soils by applying static pressure, by applying impacts, or by applying vibration, or any combination thereof, to the above ground portion of the sampler extensions until the sampler has been advanced to the desired sampling depth. The sampler is recovered from the hole and the sample removed from the sampler. The sampler is cleaned and the procedure repeated for the next desired sampling interval. Sampling can be continuous for full depth borehole logging or incremental for specific interval sampling. Samplers used can be protected type for controlled specimen gathering or unprotected for general soil specimen collection.

#### 5. Significance and Use

5.1 Direct push methods of soil sampling are used for geologic investigations, soil chemical composition studies, and water quality investigations. Examples of a few types of investigations in which direct push sampling may be used include site assessments, underground storage tank investigations, and hazardous waste site investigations. Continuous sampling is used to provide a lithological detail of the subsurface strata and to gather samples for classification and index or for chemical testing. These investigations frequently are required in the characterization of hazardous waste sites. Samples, gathered by direct push methods, provide specimens necessary to determine the chemical composition of soils, and in most circumstances, contained pore fluids (3).

5.2 Direct push methods can provide accurate information on the characteristics of the soils encountered and of the chemical composition if provisions are made to ensure that discrete samples are collected, that sample recovery is maximized, and that clean decontaminated tools are used in the sample gathering procedure. For purposes of this guide, "soil"

shall be defined in accordance with Terminology D 653. Using sealed or protected sampling tools, cased boreholes, and proper advancement techniques can assure good representative samples. Direct push boreholes may be considered as a supplementary part of the overall site investigation or may be used for the full site investigation if site conditions permit. As such, they should be directed by the same procedural review and quality assurance standards that apply to other types of subsurface borings. A general knowledge of subsurface conditions at the site is beneficial.

5.3 Soil strata profiling to shallow depths may be accomplished over large areas in less time than with conventional drilling methods because of the rapid sample gathering potential of the direct push method. More site time is available for actual productive investigation as the time required for ancillary activities, such as decontamination, rig setup, tool handling, borehole backfill, and site clean-up is reduced over conventional drilling techniques. Direct push soil sampling has benefits of smaller size tooling, smaller diameter boreholes, and minimal investigative derived waste.

5.4 The direct push soil sampling method may be used as a site characterization tool for subsurface investigation and for remedial investigation and corrective action. The initial direct push investigation program can provide good soil stratigraphic information depending on the soil density and particle size, determine ground water depth, and provide samples for field screening and for formal laboratory analysis to determine the chemical composition of soil and contained pore fluids. Use of this method, results in minimum site disturbance and no cuttings are generated.

5.5 This guide may not be the correct method for investigations in all cases. As with all drilling methods, subsurface conditions affect the performance of the sample gathering equipment and methods used. Direct push methods are not effective for solid rock and are marginally effective in partially weathered rock or very dense soils. These methods can be utilized to determine the rock surface depth. The presence or absence of ground water can affect the performance of the sampling tools. Compact gravelly tills containing boulders and cobbles, stiff clay, compacted gravel, and cemented soil may cause refusal to penetration. Certain cohesive soils, depending on their water content, can create friction on the sampling tools which can exceed the static delivery force, or the impact energy applied, or both, resulting in penetration refusal. Some or all of these conditions may complicate removal of the sampling tools from the borehole as well. Sufficient retract force should be available to ensure tool recovery. As with all borehole advancement methods, precautions must be taken to prevent cross contamination of aquifers through migration of contaminants up or down the borehole. Regardless of the tool size, the moving of drilling and sampling tools through contaminated strata carries risks. Minimization of this risk should be a controlling factor in selecting sampling methods and drilling procedures. The user should take into account the possible chemical reaction between the sample and the sampling tool itself, sample liners, or other items that may come into contact with the sample (3, 4).

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or vapor sampling, or both, with soil sampling in the same investigation. Guides D 6001 and D 4700 can provide additional information on procedures to be used in such combined efforts.

## 6. Criteria for Selection

6.1 Important criteria to consider when selecting sampling tools include the following:

- 6.1.1 Size of sample.
- 6.1.2 Sample quality (Class A,B,C,D) for physical testing. Refer to Practice D 4220.
- 6.1.3 Sample handling requirements, such as containers, preservation requirements.
- 6.1.4 Soil conditions anticipated.
- 6.1.5 Ground water depth anticipated.
- 6.1.6 Boring depth required.
- 6.1.7 Chemical composition of soil and contained pore fluids.
- 6.1.8 Probability of cross contamination.
- 6.1.9 Available funds.
- 6.1.10 Estimated cost.
- 6.1.11 Time constraints.
- 6.1.12 History of tool performance under anticipated conditions (consult experienced users and manufacturers).
- 6.2 Important criteria to consider when selecting direct push equipment include the following:
  - 6.2.1 Site accessibility.
  - 6.2.2 Site visibility.
  - 6.2.3 Soil conditions anticipated.
  - 6.2.4 Boring depth required.
  - 6.2.5 Borehole sealing requirements.
  - 6.2.6 Equipment performance history.
  - 6.2.7 Personnel requirements.
  - 6.2.8 Decontamination requirements.
  - 6.2.9 Equipment grouting capability.
  - 6.2.10 Local regulatory requirements.

## 7. Apparatus

7.1 *General*—A direct push soil sampling system consists of a sample collection tool, hollow extension rods for advancement, retrieval, and transmission of energy to the sampler, and an energy source to force sampler penetration. Auxiliary tools are required to handle, assemble and disassemble, clean, and repair the sample collection tools and impact surfaces. Necessary expendable supplies are sample containers, sample container caps, sample liners, sample retainers, appropriate lubricants, and personal safety gear.

### 7.2 Direct Push Tool Systems:

7.2.1 *Two Tube System*—An outer casing and an inner extension rod with a sampler attached (see Fig. 1) are advanced simultaneously into the soil for the length capacity of the sampler. The sampler is removed from the borehole and a new sampler barrel or plug bit is inserted for each increment of depth. Two-tube sampling systems also may incorporate sample gathering chambers that are fitted into the outer casing shoe. These sample barrels are designed to create a minimum of sample disturbance while gathering high quality specimens (see Fig. 2). Samplers are held in the proper position by different methods, such as extension rods, pneumatic or me-

chanical packers, spring activated latches, or other devices (see Figs. 1 and 2). Locking devices must be strong enough to hold the sampler while penetrating the sample strata. The outer casing supports the borehole wall. Sample retrieval is expedited by the cased hole and continuous sampling is simplified. Continuous sampling may be a benefit to lithological logging. A cased borehole can be sealed from the bottom up as the casing is extracted (see Section 10). A cased hole may reduce the risk of contamination migration down the borehole and sample cross contamination. The two-tube system is more susceptible to soil friction because of its larger diameter and may require larger direct push energy than single-tube systems. An oversized drive shoe is sometimes used to reduce friction and buckling but may increase the risk of contamination migration down the borehole.

7.2.2 *Single Tube System*—The single tube system (see Fig. 3), uses a hollow extension/drive rod to advance and retrieve the sampler. The sampler is attached to the bottom of the extension/drive rod. A drive cap is added to the top of the extension/drive rod and the sampler is pushed into the soil. Extension/drive rods generally are smaller in diameter than the sampler. The single tube system minimizes effort for discrete interval sampling under many subsurface conditions. Tool connection time per interval is reduced. Time of removal and reinsertion of samplers into the borehole is affected by soil conditions. Repeated movement of the sampler through contaminated subsurface strata may increase the risk of contamination migration down the borehole. Bottom up borehole sealing may require re-entry in soil formations that collapse (see Section 10).

### 7.3 Samplers:

7.3.1 *Split Barrel Samplers*—Split barrel samplers (see Fig. 4) are available for use with direct push drilling methods and are available in various sizes up to 3.0 in. (76.2-mm) inside diameter. The inside tolerance should allow for use of liners. Split barrel sampler shoes used in two tube systems must be of sufficient diameter to prevent the intrusion of soil between the outer diameter of the shoe and the inside wall of the outer tube. Split barrel shoes should be replaced when the leading edge is damaged. Damaged shoes can negatively affect sample recovery. Samplers can be used with or without ball check value fitted split barrel heads. The ball check prevents uphole fluids from flowing down through the sample. Where soil sampling will be performed below the water table, the split barrel head, equipped with a ball check, should be used. The open split barrel is best used with the two tube system because the outer casing protects the borehole against cave-in or sloughing, or in soils in which the borehole wall will not collapse. Split barrel sealing systems are available. Split barrel sections can be joined to create a sampler with a nominal sample length capacity of 48 in. (1.22 m). It is understood that samplers with usable lengths beyond 24 in. (0.61 m) are used to advantage in certain soil types; however, the added weight of the soil sample in the chamber and the added friction within the sampler may prevent loose soils from entering the sampler, affecting sample recovery and representativeness. Split barrel samplers can be fitted with a basket to improve recovery in cohesionless soils. Retainers are available in many styles and materials. Retainers

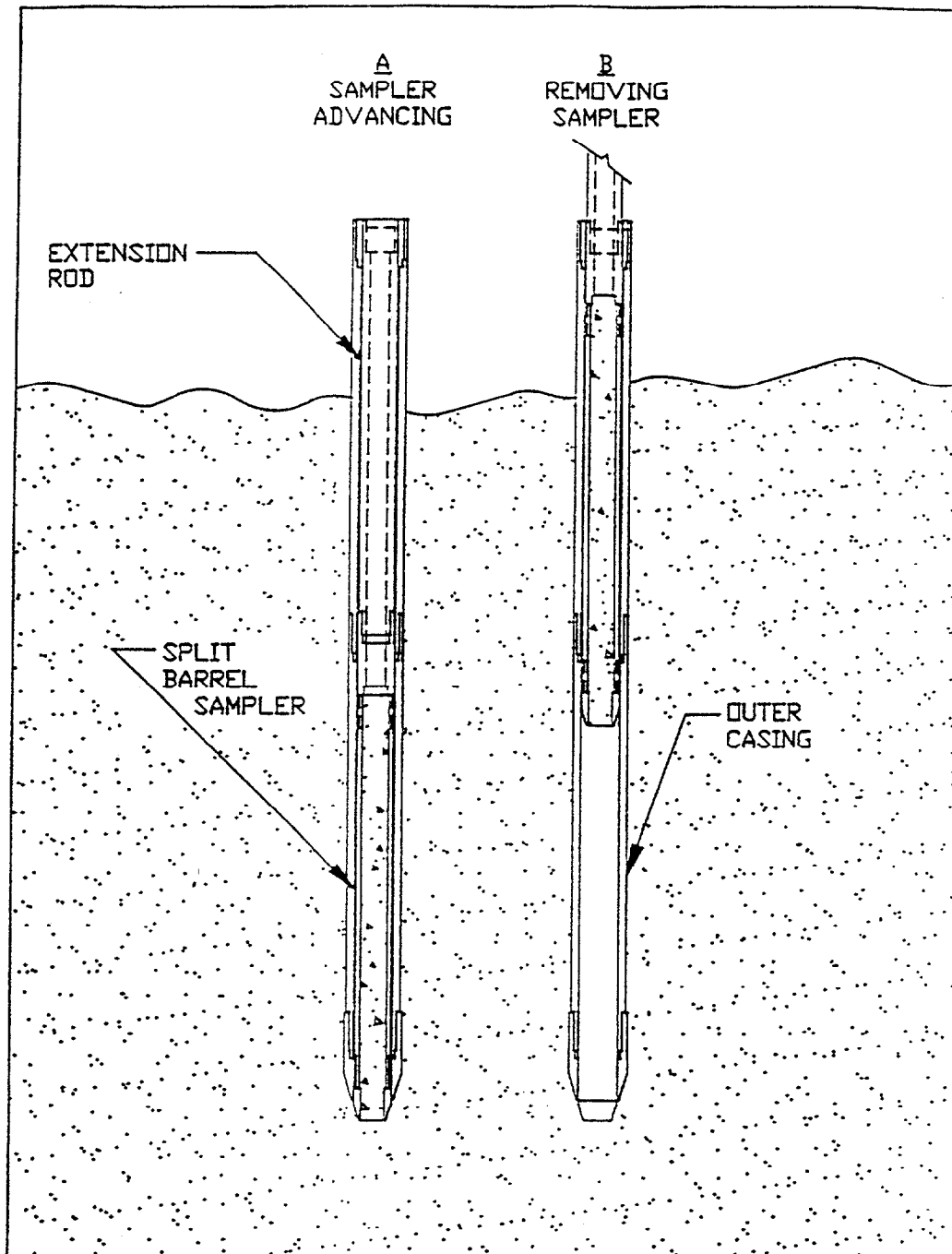


FIG. 1 Split Spoon Sampling, Two Tube System

should allow the passage of softer soils. Stiff retainers can reduce specimen recovery in soft soils.

#### 7.3.2 Solid Barrel Samplers:

**7.3.2.1 Open Solid Barrel Samplers**—Open solid barrel (see Fig. 5) samplers are used with all types of direct push sampling systems. Solid barrels can have inside diameters ranging up to 3 in. (76.2 mm). Barrel lengths range from 6 in. (152.4 mm) to 5 ft (1.53 m). Solid barrel samplers may be one piece or segmented. Sample liners should be used to facilitate removal of the sample from the solid barrel. Without the use of liners, samples are extruded mechanically. Liner lengths should fit sampler barrel lengths. Solid barrel samplers are generally

assembled with a removable cutting shoe and a drive head (see Fig. 6). The head provides a backing to hold the liner stationary while the sampler is advanced and serves as a connector to the extension/drive rods. The shoe is manufactured to hold the liner stationary during the soil collection procedure. The liner should be slightly larger than the inner diameter of the cutting shoe. It may be slipped over the cutting shoe (see Fig. 6) or nested inside of the cutting shoe (see Fig. 7). The shoe is manufactured to cut the sample to a slightly undersized diameter allowing it to pass into the sample liner with a minimum of side friction to reduce sample disturbance. The amount of specimen contact with the inside of the shoe should



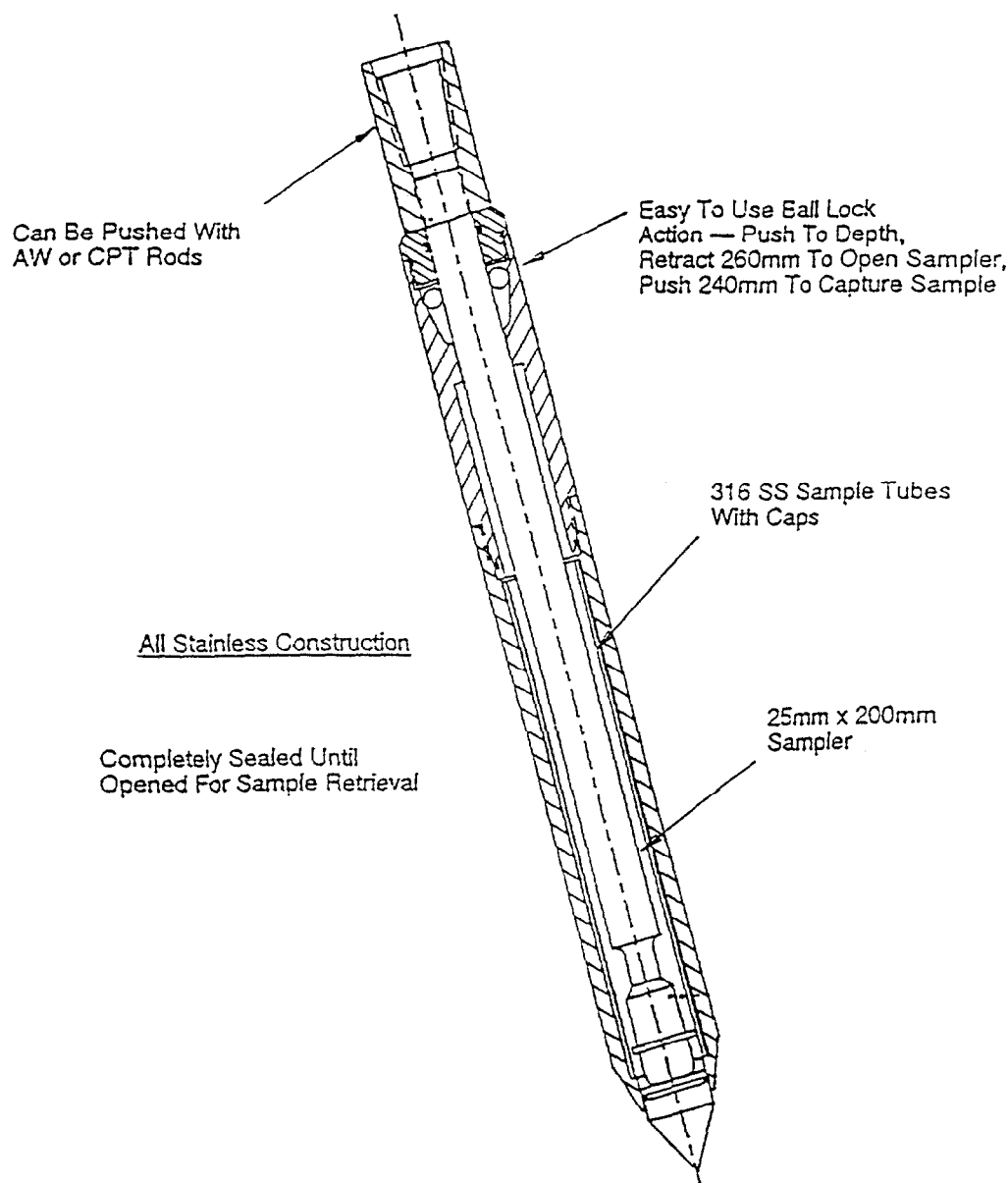


FIG. 2 Sealed Sample Barrel, Single Tube System

be held to the minimum distance possible to aid in achieving the maximum amount of recovery.

**7.3.3 Closed Barrel Sampler**—Closed barrel samplers (see Figs. 2 and 3, Figs. 5-8) are devices, which remain sealed shut until an action is taken to open the sample receiving chamber. These samplers are used most often for single events (discrete point sampling) where a sealed sampler is required to avoid cross contamination or in circumstances where borehole wall stability cannot be assured. The shoe sealing device generally is a point designed to allow the continuous flow of soil around and past the sampler until such time as it is removed or released. The piston point can be fitted with seals, such as "O" rings at top and bottom to hold fluid out until sampling the desired interval. The piston rod extends through the sample retaining liner and must be released or removed for the soil to enter (see Fig. 3, Fig. 5, Fig. 7). The piston can be removed manually before sampling or be displaced by the soil entering

the sampler chamber. Using the displacement method can result in reduced recovery if sampled soils do not have sufficient strength to displace the piston. Pistons are locked in place by several methods, such as a spring loaded latch. The latch holds several balls (see Fig. 2, Fig. 7, Fig. 8) into a groove in the latch coupling. When the latch is released by lifting up on the latch stem, the balls slip back into the latch chamber allowing the piston to be removed. Another method uses a locking screw. A reverse thread pin (Fig. 3, Fig. 6) is positioned in the sampler head to prevent the piston from being displaced by the soil when advancing the sampler. At the sampling interval, small diameter extension rods are inserted through the sampler extension/drive rods and rotated clockwise to unscrew the locking pin. A third method uses an inflated packer. An inflated packer (see Fig. 9) is attached to the top of the sampler barrel. The sample barrel is lowered into position in the drive casing and the packer inflated. The packer is deflated to release

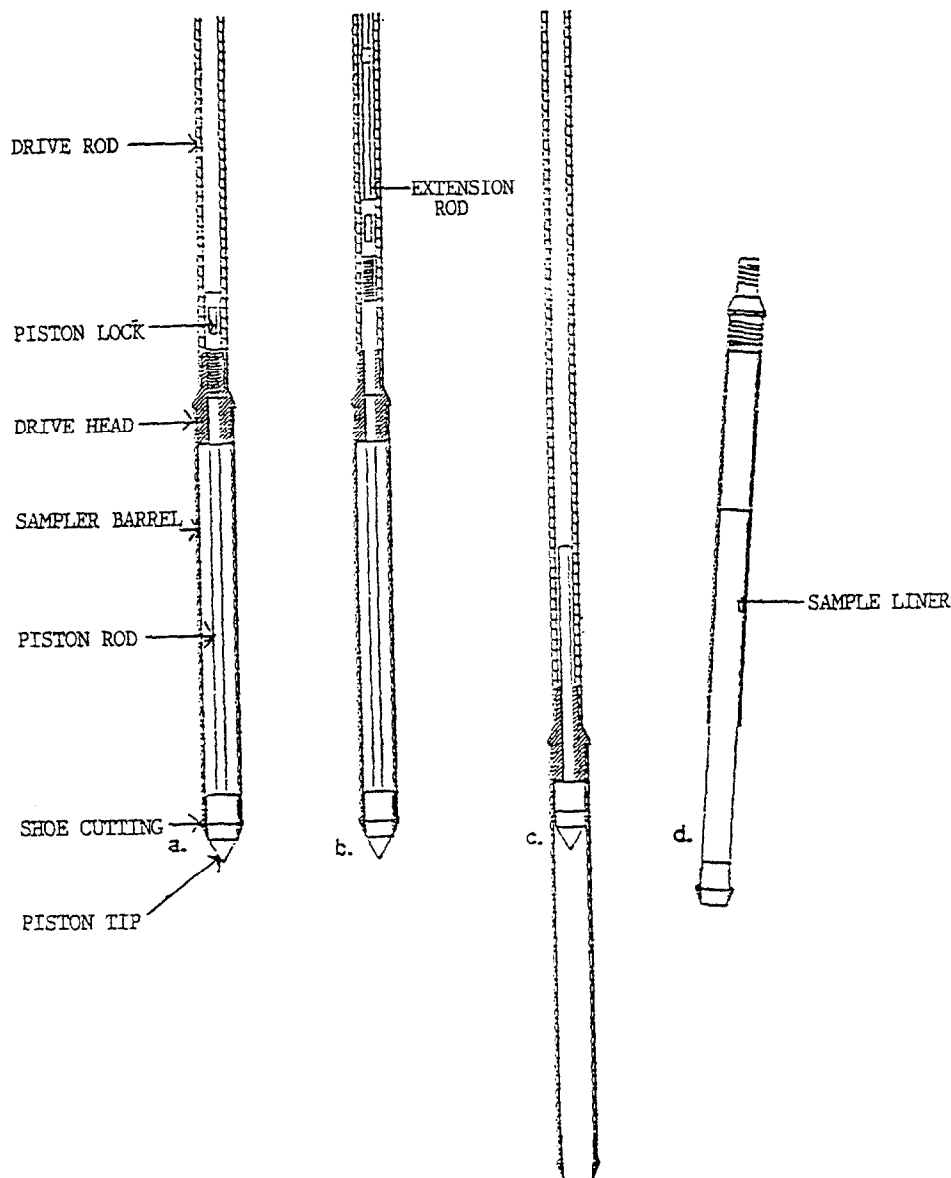


FIG. 3 Driving and Sampling, Single Tube System

- (a) Driving the sealed sampler. (b) Removing the stop-pin.  
(c) Collecting a sample (d) Recovering sample in liner.

and the sample barrel is recovered after being advanced the sampling interval.

**7.3.4 Thin Wall Tube**—A 1.0-in. (25.4-mm) diameter thin wall tube (see Fig. 10) is available for use with direct push equipment and is manufactured according to Practice D 1587. Thin wall tubes can be effective when used with dual tube direct push systems as the borehole must be kept clear of disturbed soil prior to gathering a sample. Thin wall tubes may be effective in cohesive soils with single tube systems when the borehole can be kept clear of disturbed soil. Thin wall tubes must have an outside diameter that will allow passage through the outer casing. The thin wall tube can be operated in accordance with Practice D 1587, or it can be advanced using the percussion hammer of the direct push equipment. The primary use of the thin wall tube is to gather relatively undisturbed samples in cohesive soils. Sealing of thin wall tube

ends should be completed in accordance with Practice D 4220. Fixed piston apparatus (see Fig. 10) also is available for use with thin walled tubes. The fixed piston action allows the sampling of very soft formations, which may not be retained in conventional samplers. In certain soil formations, the thin wall tube provides the best method to collect an undisturbed sample.

**7.3.5 Sampler Extension/Drive Rods**—Sampler extension/drive rods are lengths of rod or tube generally constructed of steel to withstand the pushing or percussion forces applied. Extension drive rods are available in various lengths. Rod lengths should be mated with casing and sampling equipment used. Thread types and classes vary between equipment manufacturers. Rod joints can be sealed to prevent fluid intrusion with "O" rings, Teflon<sup>®</sup> washers or Teflon<sup>®</sup> tape. Because of the percussive effort, joint seals should be checked for each sampling effort. Extension/drive rods should have

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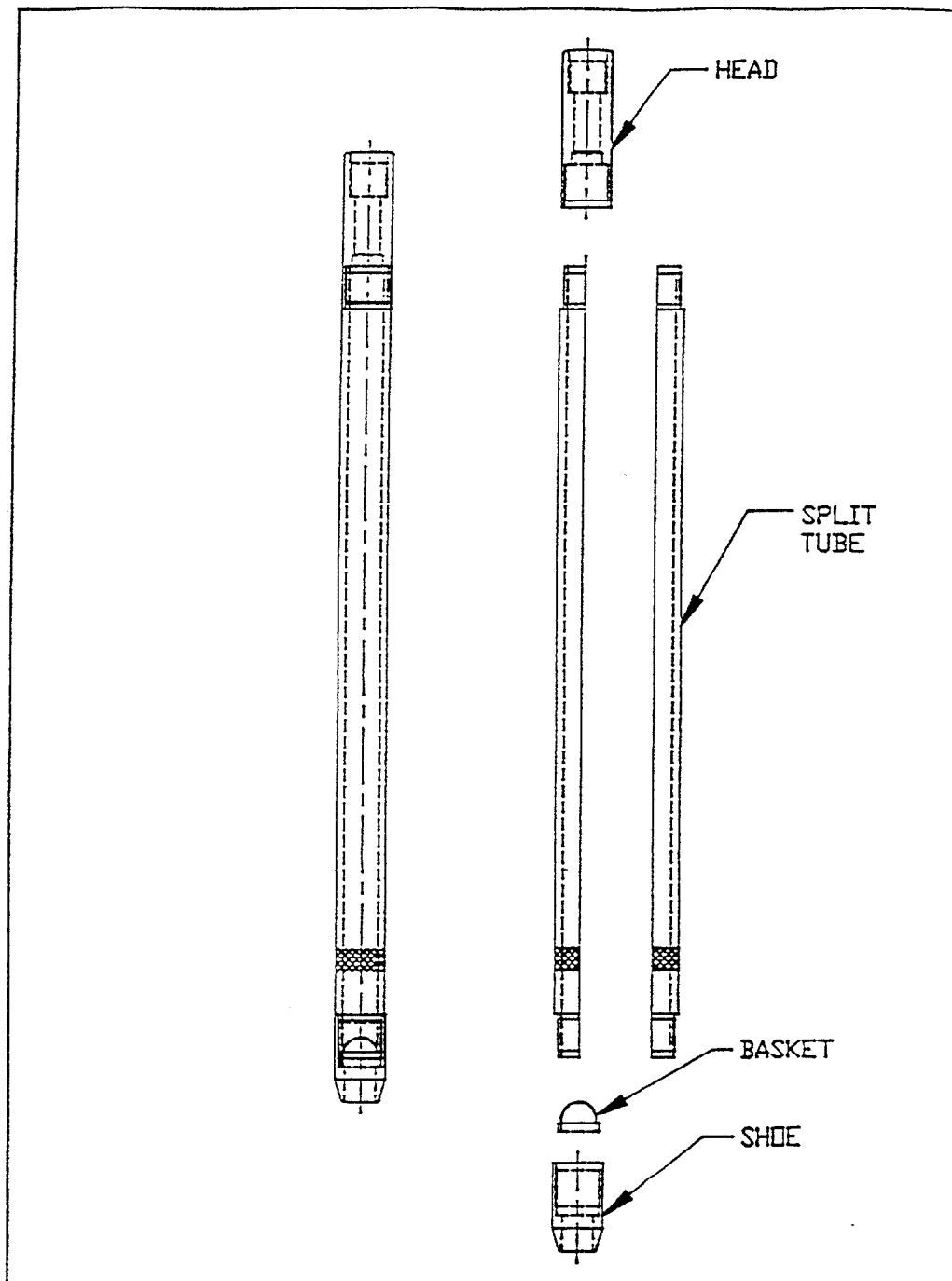


FIG. 4 Split Barrel Sampler, Two Tube System

sufficient inside diameter to accommodate the equipment necessary to perform the desired action.

**7.3.6 Sampler Liners**—Sampler liners are used to collect and store samples for shipment to laboratories, for field index testing of samples and for removing samples from solid barrel type samplers. Liners are available in plastics, Teflon<sup>®</sup>, brass, and stainless steel. Other materials can be used as testing needs dictate. Liners are available in lengths from 6 in. (152.4 mm) to 5.0 ft (1.53 m). Liner material selection often is based on the chemical composition of liner/soil to minimize sample reaction with liner. Most liner use is short term as samples are

subsampled and preserved immediately on site. A general rule for liner selection is stainless steel for organic compounds and plastic for metals. Teflon<sup>®</sup> may be required for mixed wastes and for long time storage. Liners should be sealed in accordance with Practice D 4220 when samples are collected for physical testing. Other appropriate procedures must be used when samples are collected for environmental analysis (see Practices D 3694) (1, 2). Liners generally are split in the field for subsampling. Individually split liners are available in some sizes for field use. The liner should have a slightly larger inside diameter than the soil specimen to reduce soil friction and

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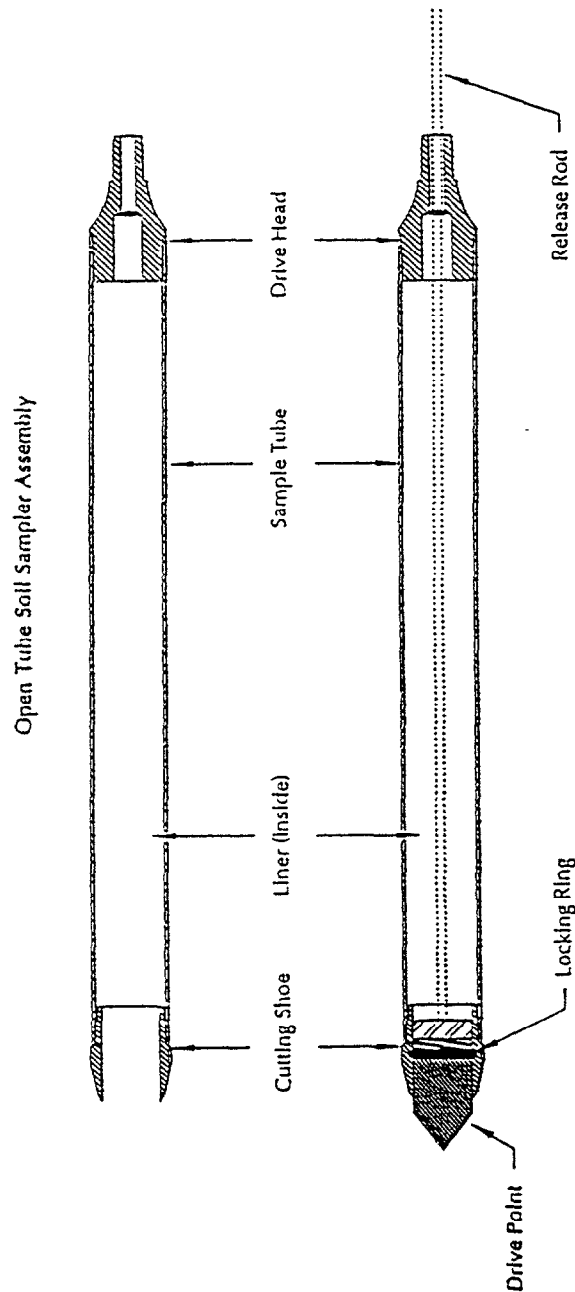


FIG. 5 (A) Open and (B) Closed Piston Sampler Assembly, Single Tube System

enhance recovery. When a slightly oversized liner is used, the potential for air space exists around the sample. Certain chemical samples may be affected by the enclosed air. Liners having less tolerance may be required and a shortened sampled interval used to reduce friction in the liner. Metal liners can be reused after proper cleaning and decontamination. Plastic liners should be disposed of properly after use.

**7.3.7 Sample Containers**—Sample containers should be prescribed according to the anticipated use of the sample. Samples taken for chemical testing may require decontaminated containers with specific preservatives. Practice D 3694 provides information on some of the special containers

and preservation techniques required (1, 2). These containers generally will be decontaminated to specific criteria. Samples for geotechnical testing require certain minimum volumes and specific handling techniques. Practice D 4220 offers guidance for sample handling of samples submitted for physical testing.

**7.4 Direct Push Power Sources**—Soil probing percussion driving systems, penetrometer drive systems, and rotary drilling equipment may be used to drive casings and direct push soil sampling devices. The equipment should be capable of applying sufficient static force, or dynamic force, or both, to advance the sampler to the required depth to gather the desired sample. The system must have adequate retraction force to

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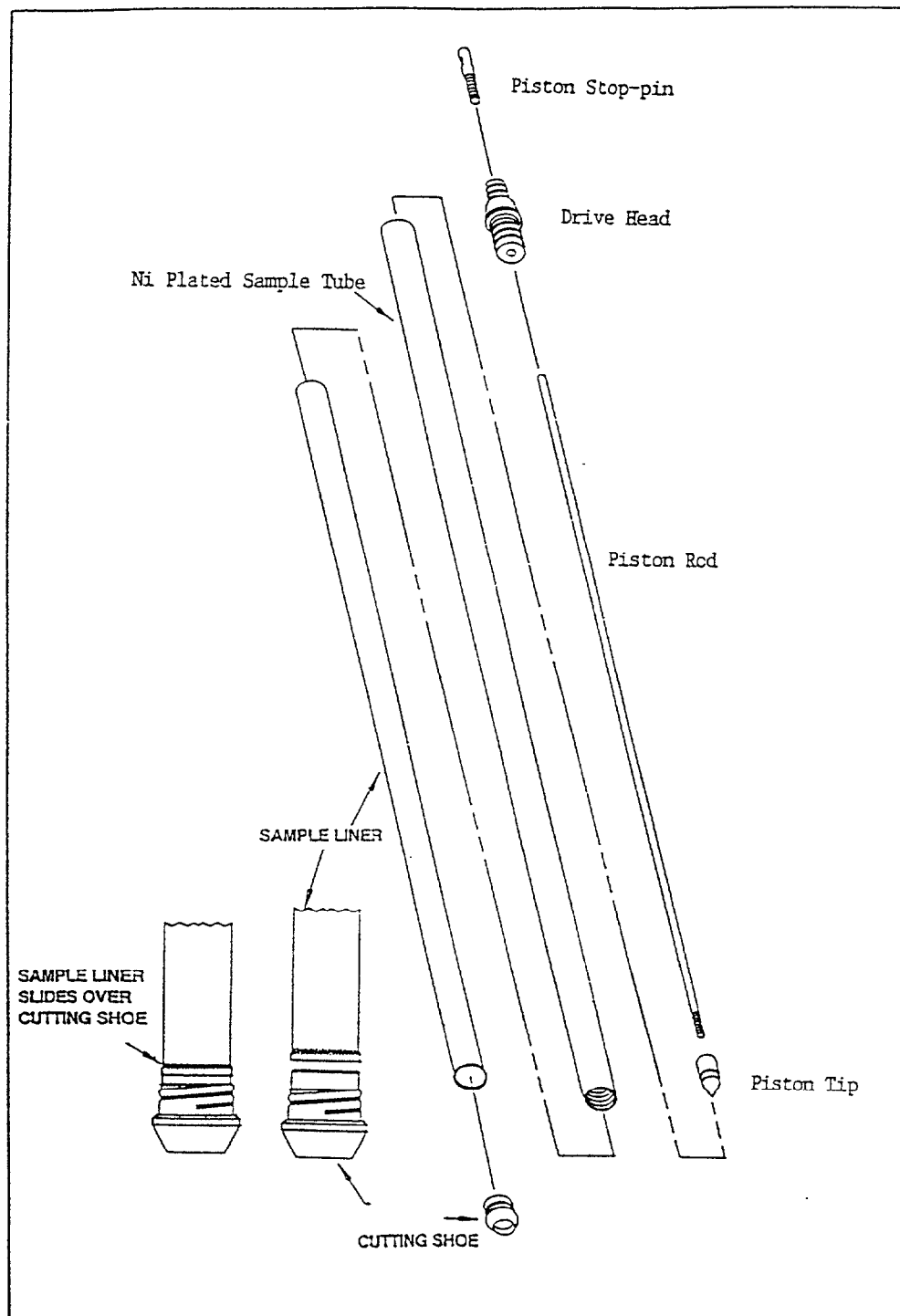


FIG. 6 Sampler Parts, Single Tube System

remove the sampler and extension/drive rods once the selected strata has been penetrated. Rotation of the drill string can be added during insertion, as well as during retraction if the drive system can impart rotation.

**7.4.1 Retraction Force**—The retraction force can be applied by direct mechanical pull back using the hydraulic system of the power source; line pull methods using mechanical or hydraulic powered winches, or cathead and rope windlass type devices. Winches used with direct push technology should

have a minimum of 2000 lb (907 kg) top layer rating capacity and a line speed of 400 ft (121.96 m)/min to provide effective tool handling. Direct push sampling tools can be retracted by back pounding using weights similar to those of standard penetration testing practices. Backpounding to recover samples can affect recovery and cause disturbances to the sample. Other forms of extraction, such as jacking, that do not cause undue disturbance to the sample, are preferable.

**7.4.2 Percussion Devices**—Percussion devices for use wi.

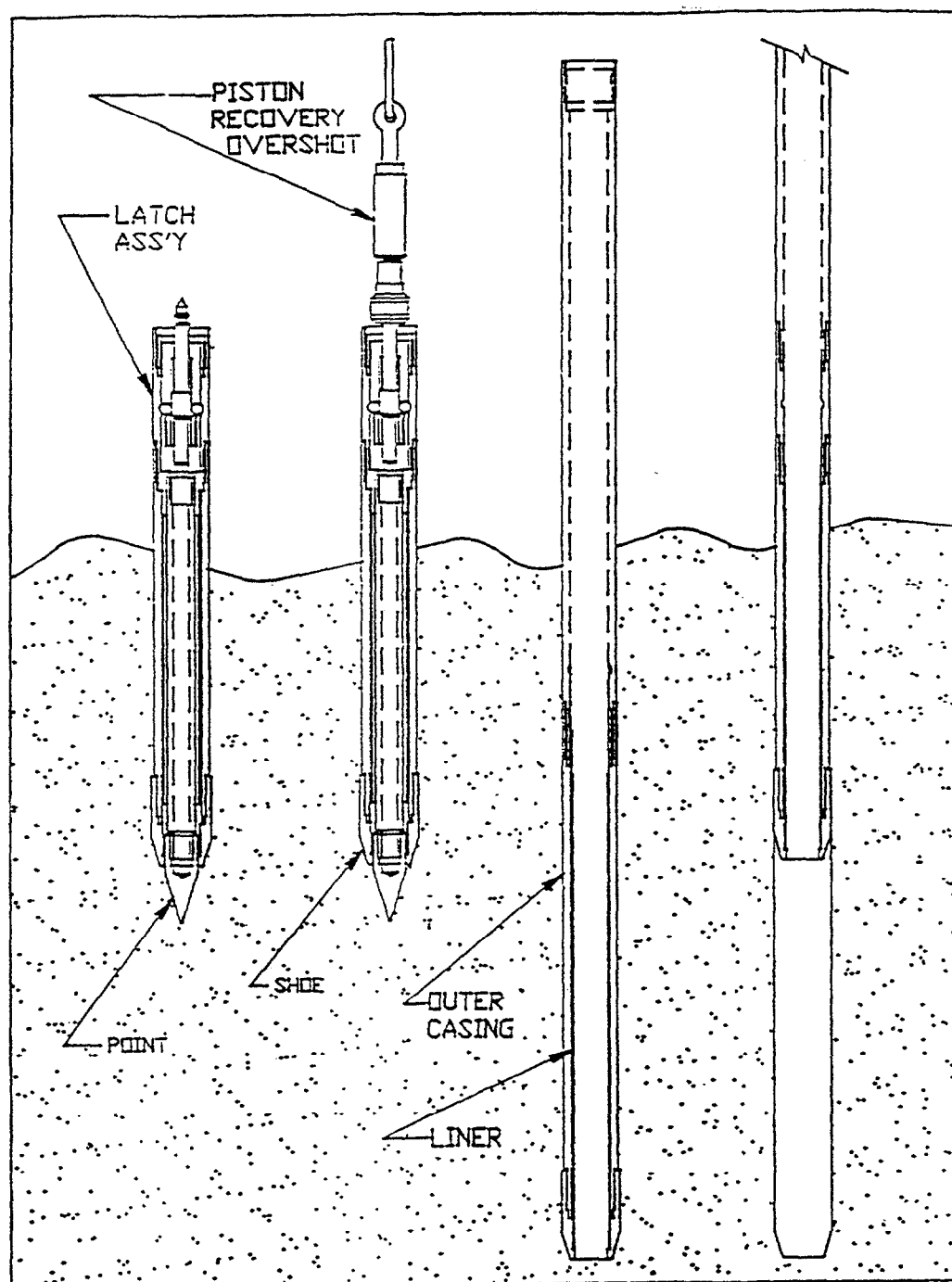


FIG. 7 Closed Solid Barrel Sampler, Single Tube System

direct push methods are hydraulically-operated hammers, air-operated hammers, and mechanically-operated hammers. Hydraulically-operated hammers should have sufficient energy to be effective in moving the samplers through the subsurface strata. The maximum energy application is dependent on the tools used. Hammer energy that exceeds tool tolerance will result in tool damage or loss and will not achieve the goal of collecting high quality samples. Air-operated hammers should be capable of delivering sufficient energy, as well. Hammer systems utilizing hydraulic oil or air should be operated in the range specified by the manufacturer. Manually-operated ham-

mers can be used to advance direct push tools. These hammers can be operated mechanically or manually using cathead and rope. These systems generally involve using 140 lb, standard penetration (see Test Method D 1586) hammers, which can work well for direct push sampling. In operation, these hammers tend to be slower than hydraulic hammers and can cause tool damage if direct push tools are not designed to take the heavy blows associated with these hammers. The hydraulic- and air-operated hammers strike up to 2000 blows/min. In addition to the energy transferred, the rapid hammer action sets up a vibratory effect, which also aids in penetration.

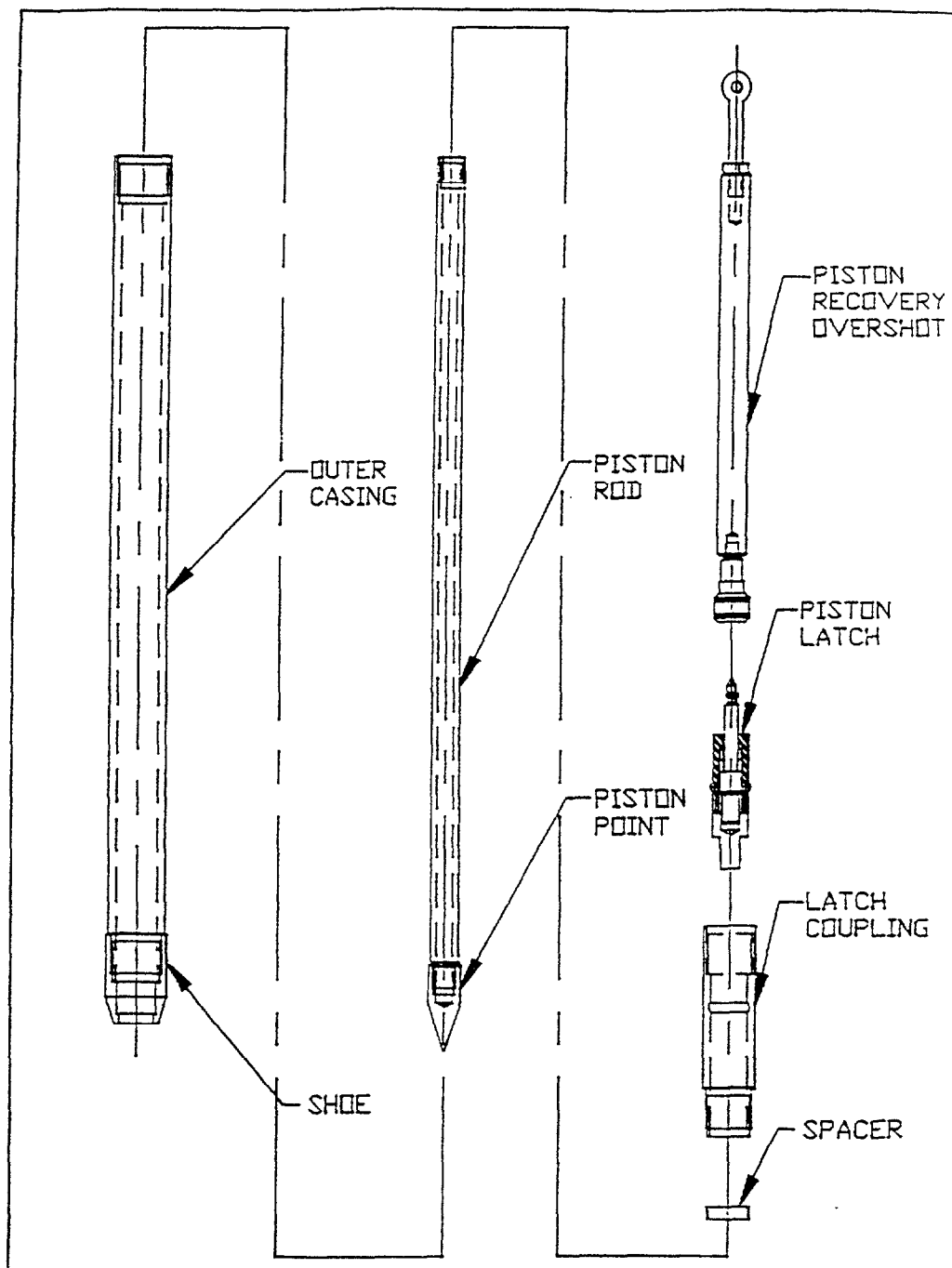


FIG. 8 Closed Solid Barrel Sampler, Single Tube System

This vibratory effect, along with the percussive effort, may disturb some soil samples.

**7.4.3 Static Push Systems**—Cone penetrometer systems are an example of static push systems. They impart energy to the sampler and extension rods by using hydraulic rams to apply pressure. The pressure applied is limited to the reactive weight of the drive vehicle. Retraction of the sampler and extension rods is by static pull from the hydraulic rams.

**7.4.4 Vibratory/Sonic Systems**—These systems utilize a vibratory device, which is attached to the top of the sampler extension rods. Reactive pressure and vibratory action are applied to the sampler extensions moving the sampler into the

formation. In certain formations, sample recovery and formation penetration is expedited; however, all formations do not react the same to vibratory penetration methods.

**7.4.4.1 Sonic or Resonance Drilling Systems**—These are high powered vibratory systems that can be effective in advancing large diameter single or dual tube systems. They generally have depth capabilities beyond the smaller direct push systems.

**7.4.5 Rotary Drilling Equipment**—Direct push systems are readily adaptable to rotary drill units. The drill units offer a ready hydraulic system to operate percussion hammers, as well as reactive weight for static push. Because most drills are

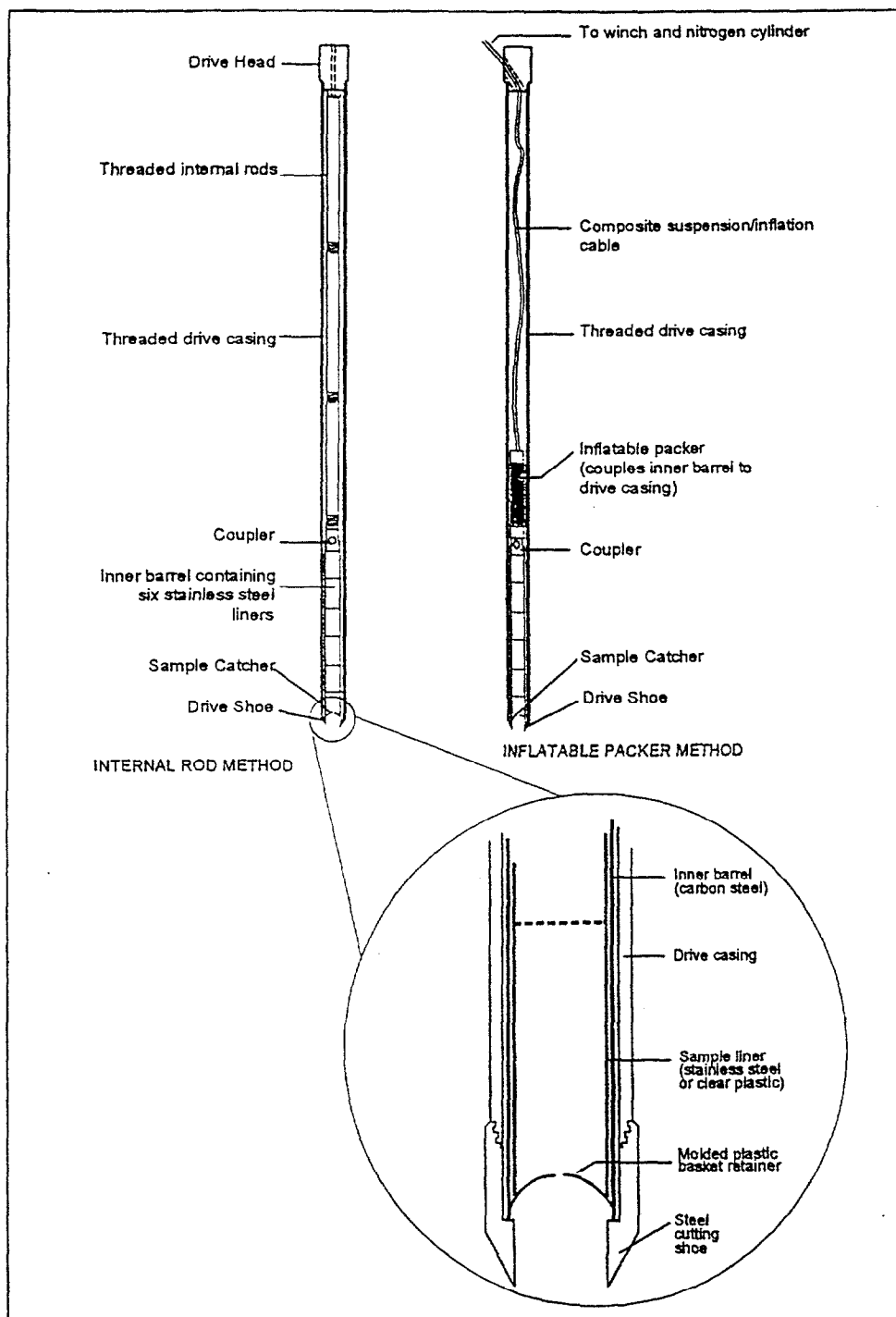


FIG. 9 Sampler Holding Methods, Two Tube System

equipped with leveling jacks, better weight application is achieved. Vertical pushing is improved because of the ability to level the machine. Tool handling is facilitated by high speed winches common to drilling rigs, extended masts for long tool pulls, and longer feed stroke length. Drill units with direct push adaptations also offer drilling techniques should obstacles be encountered while using direct push technology. Large drill units may have reactive weights that can exceed the tool capacity, thereby resulting in damaged tools.

## 8. Conditioning

8.1 *Decontamination*—Sampling equipment that will contact the soil to be sampled should be cleaned and decontaminated before and after the sampling event. Extension rods should be cleaned prior to each boring to avoid the transfer of contaminants and to ease the connecting of joints. Thread maintenance is necessary to ensure long service life of the tools. Sample liners should be kept in a sealed or clean



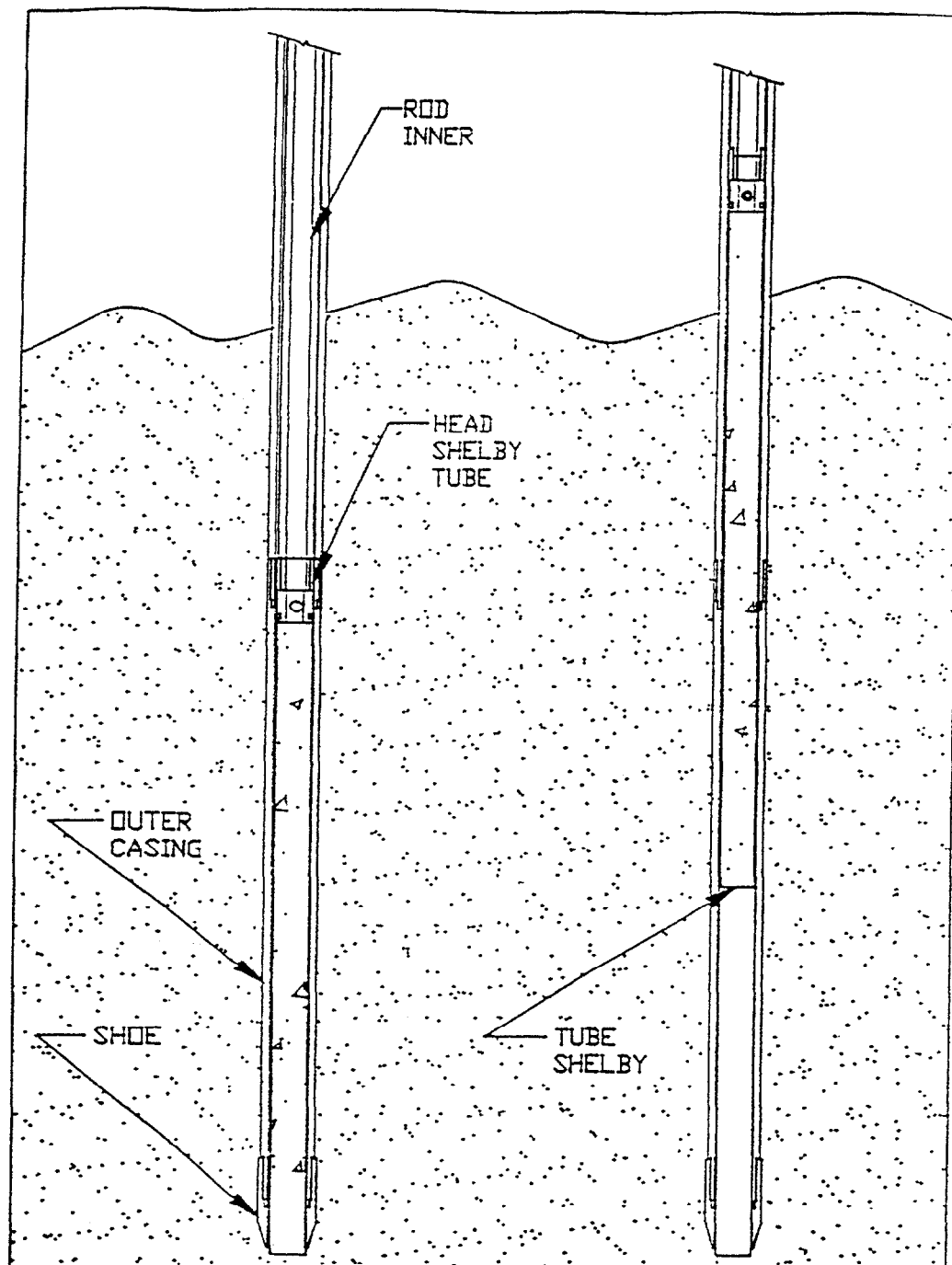


FIG. 10 Thin Wall Tube Sampler, Two Tube System

environment prior to use. Reusable liners should be decontaminated between each use. All ancillary tools used in the sampling process should be cleaned thoroughly, and if contaminants are encountered, decontaminated before leaving the site. It should not be assumed that new tools are clean. They should be cleaned and decontaminated before use. Decontamination should be performed following procedures outlined in Practice D 5088 along with any site safety plans, sampling protocols, or regulatory requirements.

**8.2 Tool Selection**—Prior to dispatch to the project site an inventory of the necessary sampling tools should be made.

Sample liners, containers, sampling tools, and ancillary equipment should be checked to ensure its proper operation for the work program prescribed. Sampling is expedited by having two or more samplers on site. Since samples can be recovered quite fast, a supply of samplers will allow a boring to be completed so other functions can be performed while samples are being processed. A backup tool system adaptable to and within the capabilities of the power source should be available should the original planned method prove unworkable. Materials for proper sealing of boreholes should always be available at the site (5-7).

## 9. Procedure

9.1 While procedures for direct push soil sampling with two common direct push methods are outlined here, other systems may be available. As long as the basic principles of practice relating to sampler construction and use are followed, other systems may be acceptable.

9.2 *General Set-Up*—Select the boring location and check for underground and overhead utilities and other site obstructions. Establish a reference point on the site for datum measurements, and set the direct push unit over the boring location. Stabilize and level the unit, raise the drill mast or frame into the drilling position, and attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit into position over the borehole, save a portion of the sliding distance for alignment during tool advancement, and ready the tools for insertion.

9.2.1 *Tool Preparation*—Inspect the direct push tools before using, and clean and decontaminate as necessary. Inspect drive shoes for damaged cutting edges, dents, or thread failures as these conditions can cause loss of sample recovery and slow the advancement rate. Where permissible, lubricate rod joints with appropriate safe products, and check impact surfaces for cracks or other damage that could result in failure during operations. Assemble samples and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed.

9.2.2 *Sample Processing*—Sample processing should follow a standard procedure to ensure quality control procedures are completed. View sample in the original sampling device, if possible. Open the sampling device with care to keep disturbance to a minimum. When using liners or thin wall tubes, protect ends to prevent samples from falling out or being disturbed by movement within the liner. Measure recovery accurately, containerize as specified in the work plan or applicable ASTM procedures, and label recovered samples with sufficient information for proper identification. When collecting samples for volatile chemical analysis, sample specimens must be contained and preserved as soon as possible to prevent loss of these components. Follow work plan instructions or other appropriate documents (see Practice D 3694) when processing samples collected for chemical analysis.

### 9.3 Two Tube System:

9.3.1 *Split Barrel Sampling (see Fig. 1)*—Assemble the outer casing with the drive shoe on the bottom, attach the drive head to the top of the outer casing, and attach the sampler to the extension rods. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing. The sampler cutting shoe should contact the soil ahead of the outer casing to prevent unnecessary sample disturbance. The split spoon cutting shoe should extend a minimum of 0.25 in. (6.25 mm) ahead of the outer casing. Greater extensions may improve recovery in soft formations. Mark the outer casing to designate the required drive length, position the outer casing and sampler assembly under the drill head, and move the drill head downward to bring pressure on the tool string. If soil conditions allow, advance the sampler/

casing assembly into the soil at a steady rate slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel. If advancement is too rapid, it can result in loss of recovery because of soil friction in the shoe. Occasional hammer action during the push may help recovery by agitating the sample surface. If soil conditions prevent smooth static push advancement, activate the hammer to advance the sampler. Apply a continuous pressure while hammering to expedite soil penetration. The pressure required is controlled by subsurface conditions. Applications of excessive down pressure may result in the direct push unit being shifted off the borehole causing misalignment with possible tool damage. Stop the hammer at completion of advancement of the measured sampling barrel length. Release the pressure and move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole. At the surface remove the sampler from the extension rods and process. Soil classification is accomplished easily using split barrel samplers as the specimen is available readily for viewing, physical inspection and subsampling when the barrel is opened. Clean, decontaminate, and reassemble the sampler. Reattach the sampler to the extension rod, add the necessary extension rod and outer casing to reach the next sampling interval, and sound the borehole for free water before each sample interval. If water is present, it may be necessary to change sampling tools. Unequal pressure inside the casing may result in blow-in of material disturbing the soil immediately below the casing. Lower the sampler to its proper position, add the drive heads, and repeat the procedure. If it is desired that the pass through certain strata without sampling, install an extension rod point in lieu of the sampler. When the sampling interval is reached, remove the point and install the sampler. Advance the sampler as described. Upon completion of the borehole, remove the outer casing after instrumentation has been set or as the borehole is sealed as described in Section 10 (6).

### 9.3.2 Two Tube System—Other Samplers:

9.3.2.1 *Thin Wall Tubes*—Thin wall tubes (see Fig. 10) can be used with the dual tube system. Attach the tube to the tube head using removable screws. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 0.25 in. (6.25 mm) to contact the soil ahead of the outer casing. Advance the tube, with or without the outer casing, at a steady rate similar to the requirements of Practice D 1587. At completion of the advancement interval, let the tube remain stationary for 1 min. Rotate the tube slowly two revolutions to shear off the sample. Remove the tube from the borehole, measure recovery, and classify soil. The thin wall tube can be field extruded for on-site analysis or sealed in accordance with Practice D 4220 and sent to the laboratory for processing. Samples for environmental testing generally require the subsampling and preservation of samples in controlled containers. Soil samples generally are removed from the sampling device for storage and shipping. Thin wall tubes should be cleaned and decontaminated before and after use.

9.3.2.2 *Thin Wall Tube Piston Sampler (see Fig. 11)*—Check the fixed piston sampling equipment for proper operation of the cone clamping assembly and the condition of the

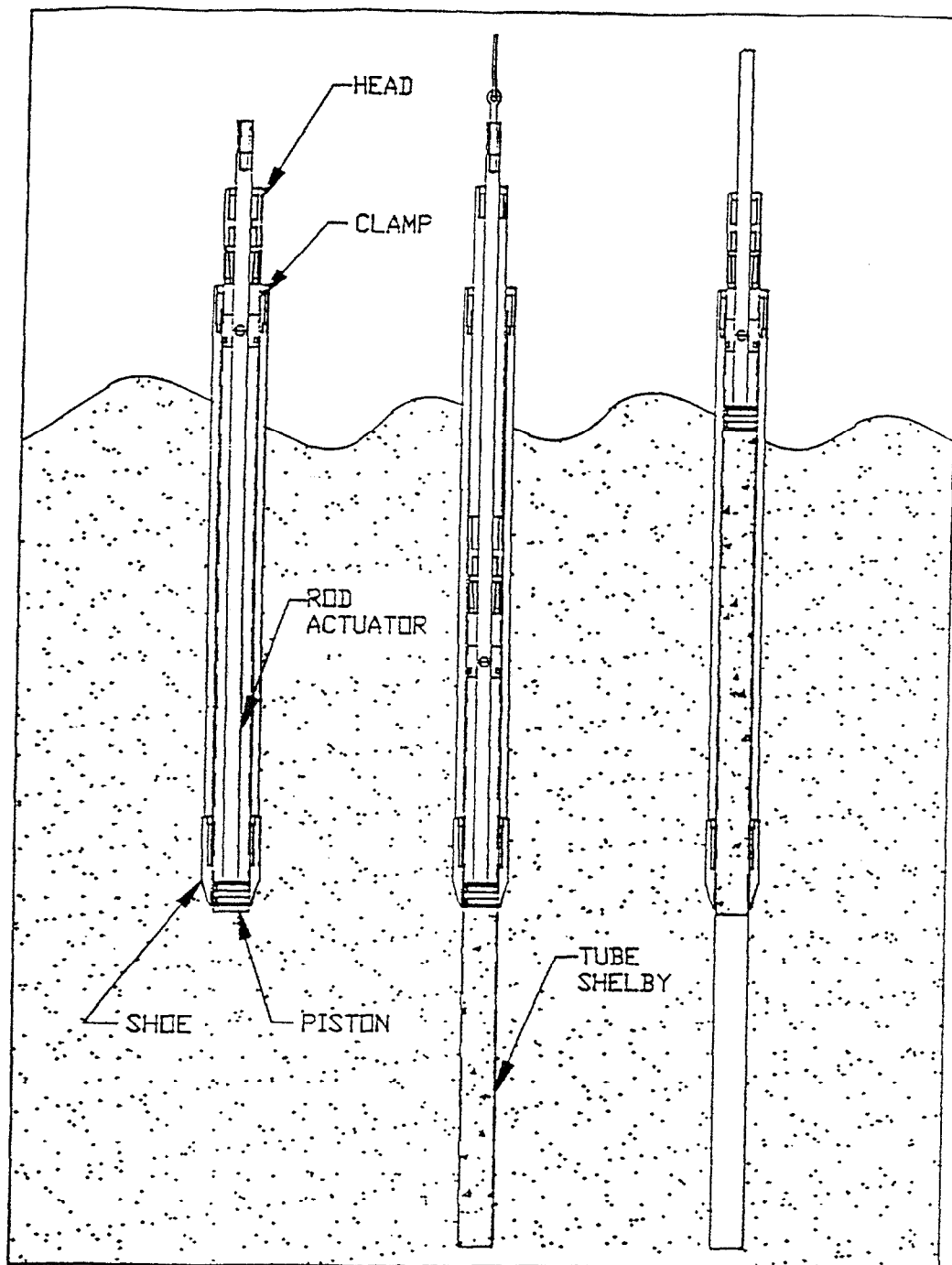


FIG. 11 Fixed Piston Sampler, Two Tube System

sealing "O" rings. Slide the thin wall tube over the piston, and attach it to the tube head. Position the piston at the sharpened end of the thin wall tube just above the sample relief bend. Attach the sampler assembly to the extension rods, and lower the sampler into position through the outer casing. Install the actuator rods through the extension rod, and attach to the actuator rod in the sampler assembly. Attach a holding ring to the top of the actuator rod string, and hook the winch cable or other hook to the holding ring to hold the actuator rods in a fixed position. Attach the pushing fork to the drill head/probe hammer, and slowly apply downward pressure to the extension

rods advancing the thin wall tube over the fixed piston into the soil for the sample increment. Rest sampler 1 min to allow sample to conform to tube. Rotate tube one revolution to shear off sample. Remove sampler assembly from borehole and process sample (6).

**9.3.2.3 Open Solid Barrel Samplers**—Use solid barrel samplers in advance of the outer casing where the soil conditions could cause swelling of split barrel samplers, or where friction against the outer casing precludes its advancement and sampling must still be accomplished. The solid, single, or segmented barrel sampler requires the use of liners for removal

the sample. The sampler must be cleaned and decontaminated before use. Use of the sampler follows the procedure described in 9.3.1.

#### 9.4 Single Tube System:

**9.4.1 Open Solid Barrel Sampler** (see Figs. 5 and 6)—Attached the required liner to the cutting shoe by insertion into the machined receptacle area or by sliding over the machined tube. Insert the liner and shoe into the solid barrel, and attach the shoe (6, 8-11). Attach the sampler head to the sampler barrel providing a backing plate for the liner. Attach the sampler assembly to the drive rod and the drive head to the drive rod. Position the assembly under the hammer anvil and advanced as described in 9.3.1. At completion of the sampling increment, remove the sampler from the borehole. Remove the filled sample liner from the barrel by unscrewing the shoe, cap the liner for laboratory testing or spit open for field processing, and advance the borehole by repeating the procedure. Because the solid barrel cannot be opened for cleaning, it may require more effort for cleaning and decontamination. The open solid barrel sampler is used in soil formations that have sufficient wall strength to maintain a borehole wall without sloughing or cave-in. In soil formations not affording such structure, other sampling methods may be required or the opening sealed. To enhance recovery in some soil strata, it may be necessary to vary the length of the sampling increment. Shorter increments generally improve recovery because of lower sample friction and compression inside the sampler chamber. Sample recovery can be enhanced in some formations by intermittent use of the percussion hammer (6, 8, 10, 11).

**9.4.2 Closed Solid Barrel Sampler** (see Figs. 5-7, Fig. 11)—Insert or attach the sample liner to the shoe, and insert the assembly into the solid barrel sampler. Install sample retaining basket if desired. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and "O" rings if free water is present, to the latching mechanism or holder. Insert the piston or packer into the liner to its proper position so the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod. Add drive head and position under the hammer anvil. Apply down pressure, hammer if needed, to penetrate soil strata above the sampling zone. When the sampling zone is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counterclockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device. Direct push or activate the hammer to advance the sampler the desired increment. Retrieve the sampler from the borehole by withdrawing the extension/drive rods. Remove the shoe, and withdraw the sample liner with sample for processing. Clean and decontaminate the sampler, reload as described, and repeat the procedure. Extreme stress is applied to the piston when driving through dense soils. If the piston releases prematurely, the sample will not be recovered from the correct interval, and a resample attempt must be made. The piston sampler can be used as a re-entry grouting tool for sealing boreholes on completion if it is equipped with a removable piston (5, 6, 7, 10, 11).

**9.4.3 Standard Split Barrel Sampler**—Attach the split spoon to an extension rod or drill rod. Using a mechanical or hydraulic hammer drive the sampler into the soil the desired increment, as long as that increment does not exceed the sampler chamber length. Remove the sampler from the borehole, disassemble, and process sample. Standard split barrel samplers can be used, as long as borehole wall integrity can be maintained and the additional friction can be overcome. If caving or sloughing occurs, the sampler tip should be sealed or other sampling tools used (9).

#### 9.5 Quality Control:

**9.5.1 Quality Control**—Quality control measures are necessary to ensure that sample integrity is maintained and that project data quality objectives are accomplished. By following good engineering principles and applying common sense, reliable site characterizations can be accomplished.

**9.5.2 Water Checks**—Water seeping into the direct push casing or connecting rods from contaminated zones may influence testing results. Periodically check for ground water before inserting samplers into borehole or into outer casings in the two tube system. If water is encountered, it may be necessary to switch to the sealed piston type samplers to protect sample integrity. Sealed piston type samples may not always be water tight. Sealing of rod or casing joints can prevent ground water from entering through the joints.

**9.5.3 Datum Points**—Establishment of a good datum reference is essential to providing reliable sample interval depths and elevators. Select datum reference points that are sufficiently protected from the work effort, and that can be located for future reference. Field measurements should be to 0.1 ft (3.05 mm). Measure extension rods as the bore advances to locate sample depth. Mark rods before driving each sample interval to determine accurate measurement of sample recovery and to accurately log borehole depth.

**9.5.4 Sample Recovery**—Sample recovery should be monitored closely and results documented. Poor recovery could indicate a change in sampling method is needed, that improper sampling practices are being conducted, or that sampling tools are incorrect. Sample recovery involves both volume and condition. Poor sample recovery should cause an immediate review of the sampling program.

**9.5.5 Decontamination**—Follow established decontamination procedures. Taking shortcuts may result in erroneous or suspect data.

### 10. Completion and Sealing

**10.1 Completion**—For boreholes receiving permanent monitoring devices, completion should be in accordance with Practice D 5092, site work plan, or regulatory requirements.

**10.2 Borehole Sealing**—Seal direct push boreholes to minimize preferential pathways for containment migration. Additional information and guidance on borehole sealing can be found in Guide D 6001 and in Guide D 5299. State or local regulations may control both the method and the materials for borehole sealing. Regulations generally direct bottom up borehole sealing as it is the surest and most permanent method for complete sealing. High pressure grouting is available for use with direct push technology for bottom up borehole sealing.

**10.2.1 Sealing by Slurry, Two Tube System**—Sound the

borehole for free water. If water exists in the casing, place the extension rods, open-ended, to the bottom of the outer casing, as a tremie. Mix the slurry to standard specifications prescribed by regulation or work plan. Pump slurry through the extension/drive rod until it appears at the surface of the outer casing. Remove the extension rods. If no free water exists in the borehole, the slurry can be placed by gravity. Top off the outer casing as it is removed from the borehole.

10.2.1.1 *Slurry Mixes*—Slurry mixes used for slurry grouting of direct push boreholes generally are of lower viscosity because of the small diameter tremie pipes required. Usable mixes are 6 to 8 gal (22.7 to 30.28 L) of water/94-lb (42.64-kg) bag of cement with 5 lb (2.27 kg) of bentonite or 24 to 36 gal (90.84 to 136.28 L) of water to 50 lb (22.68 kg) of bentonite.

10.2.2 *Sealing by Gravity—Two Tube System*—Measure the cased hole to ensure it is open to depth. Slowly add bentonite chips or granular bentonite to fill the casing approximately 2 ft. Withdraw the casing 2 ft and recheck depth. Hydrate the bentonite by adding water. Repeat this procedure as the outer casing is withdrawn. The bentonite must be below the bottom of the casing during hydration. Wetness inside the rods may affect the flow of granular bentonite to the bottom of the casing. Fill the top foot of the borehole with material that is the same as exists in that zone.

10.2.3 *Borehole Sealing Single Tube System:*

10.2.3.1 *Gravity Sealing from Surface*—If the soil strata penetrated has sufficient wall strength to maintain an open hole, then it may be possible to add sealing materials from the surface. Dry bentonite chips or granular bentonite can be placed by gravity. The borehole volume should be determined and the borehole sounded every 10 ft (3 m) to ensure bridging has not occurred. The bentonite should be hydrated by adding approximately 1 pt (0.57 L) of water for each 5 ft of filled borehole. Seal the surface with native material.

10.2.3.2 *Wet Grout Mix Tremie Sealing*—Tremie sealing methods can be used with single tube systems when borehole wall strength is sufficient to maintain an open hole or when extension rods with an expendable point are used to reenter the borehole. The grout pipe should be inserted immediately after

the direct push tools are withdrawn or through the annulus of the extension rods that have been reinserted down the borehole for grouting. Care must be taken to not plug the end of the grout pipe. Side discharge grout pipes also can be used to prevent plugging.

10.2.4 *Re-Entry Grouting*—If the borehole walls are not stable, the borehole can be re-entered by static pushing grouting tools, such as an expendable point attached to the extension/drive rods to the bottom of the original borehole. Pump a slurry through the rods as they are withdrawn. High pressure grouting equipment may be beneficial in pumping standard slurry mixes through small diameter gravity pipes. Care must be taken to ensure the original borehole is being sealed.

## 11. Record Keeping

11.1 *Field Report*—The field report may consist of boring log or a report of the sampling event and a description of the sample. Soil samples can be classified in accordance with Practice D 2488 or other methods as required for the investigation (12). Prepare the log in accordance with standards set in Guide D 5434 listing the parameters required for the field investigation program. List all contaminants identified, instrument readings taken, and comments on sampler advancement. Record any special field tests performed and sample processing procedures beyond those normally used in the defined investigation. Record borehole sealing procedures, materials used, and mix formulas on the boring log. Survey or otherwise locate the boring site to provide a permanent record of its replacement.

11.2 *Backfilling Record*—Record the method of sealing, materials used, and volume of materials placed in each borehole. This information can be added to the field boring log or recorded on a separate abandonment form.

## 12. Keywords

12.1 decontamination; direct push; ground water; sealing; soil sampling

## REFERENCES

- (1) Ford, Patrick J., and Turine, Paul J., "Characterization of Hazardous Waste Sites—A Methods Manual" Vol II, *Available Sampling Methods*, Second Edition, (Appendix A: Sample Containerization and Preservation), December 1984, EPA-600/4-84-076.
- (2) Mayfield, D., Waugh, J., and Green, R., "Environmental Sampling Guide in Environmental Testing and Analysis Product News, Vol I, No. 1, April 1993.
- (3) McLoy and Associates, Inc. "Soil Sampling and Analysis—Practice and Pitfalls," *The Hazardous Waste Consultant*, Vol 10, Issue 6, 1992.
- (4) Kay, J. N., "Technical Note," "Symposium on Small Diameter Piston Sampling with Cone Penetrometer Equipment," ASTM, 1991.
- (5) Einearson, M.D., "Wire Line Sample Recovery System," Precision Sampling Incorporated, San Fafael, CA, 1995.
- (6) Ruda, T.C., "Operating the Diedrich Drill ESP System Tools," LaPorte, IN, 1995.
- (7) Sales Division, "GS-1000 Series Grout System," Geoprobe System, 1996.
- (8) Sales Division, "Catalogue of Products," Geoprobe, Inc., Standard Operating Procedures, Technical Bulletin No. 93-660, 1993.
- (9) Sales Division, "Catalogue of Products," Diedrich Drill, Inc., LaPorte, IN, 1995.
- (10) Sales Division, "Geoprobe Macro-Core Soil Sampler, Standard Operating Procedure," Technical Bulletin No. 95-8500, November 1995.
- (11) Sales Division, "Geoprobe AT-660 Series Large Bore Soil Sampler, Standard Operating Procedures," Technical Bulletin No. 93-660, Revised: June 1995.
- (12) Boulding, J.R., "Description and Sampling of Contaminated Soils: A Field Pocket Guide," EPA-625/12-91/002; 1991 (second edition published in 1994 by Lewis Publishers).

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**APPENDIX B**  
**BOREHOLE AND SAMPLE LOGGING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
BOREHOLE AND SAMPLE LOGGING**

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**Page 1 of 14  
SOP Number: F101  
Effective Date: 02/15/98**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Test Boring Record
5.2	Soil Classification
5.3	Soil Descriptions
5.3.1	Grain Size Identification
5.3.2	Color
5.3.3	Relative Density and Consistency
5.3.4	Moisture Content
5.3.5	Stratification
5.3.6	Texture/Fabric/Bedding
5.3.7	Summary of Soil Descriptions
5.4	Sedimentary Rock Classifications
5.4.1	Rock Type
5.4.2	Color
5.4.3	Bedding Thickness
5.4.4	Hardness
5.4.5	Fracturing
5.4.6	Rock Quality Designation
5.4.7	Weathering
5.4.8	Other Characteristics
5.4.9	Additional Forms
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

**ATTACHMENT A -- EXAMPLE TEST BORING RECORD  
ATTACHMENT B -- UNIFIED SOIL CLASSIFICATION SYSTEM  
ATTACHMENT C -- SOIL AND ROCK DESCRIPTION SUMMARY**



## **BOREHOLE AND SAMPLE LOGGING**

### **1.0 PURPOSE**

This SOP provides general reference information and technical guidance on borehole and sample logging. Borehole logs provide information that is used in the determination of geological conditions, assessment of contaminant distribution, and the evaluation of remedial actions.

### **2.0 SCOPE**

This SOP provides descriptions of the standard techniques for borehole and sample logging. These techniques shall be used to provide consistent descriptions of subsurface lithology for each boring that is logged. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer may develop adequate classifications through careful, thorough observation and consistent application of the classification procedure.

### **3.0 DEFINITIONS**

Soil classifications and terms are given in Sections 5.2 and 5.3. Rock classification and terms are presented in Section 5.4.

### **4.0 RESPONSIBILITIES**

Project Manager – It is the responsibility of the Project Manager to ensure that field personnel responsible for borehole logging are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that the appropriate documents (e.g., test boring logs, field logbooks, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader – The Field Team Leader is responsible for the overall supervision of the drilling and boring activities, and for ensuring that each borehole is completely logged by the responsible drilling inspector. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The field team leader is responsible for providing copies of the test boring logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.

Drilling Inspector – The drilling inspector (site geologist) is responsible for the direct supervision of boring and sampling activities. It is the Drilling Inspector's responsibility to log each boring, document subsurface conditions, complete the appropriate forms, and direct the drilling crew (or drilling supervisor).

## 5.0 PROCEDURES

The classification of soil and rock is one of the most important jobs of a drilling inspector or site geologist. It is imperative that the drilling inspector understand and accurately use the field classification system described in this SOP to maintain a consistent flow of information. This identification is based on both visual examination and manual tests. The results of the boring activities, including soil and rock classifications, shall be recorded on a Field Test Boring Record (Attachment A) or the field notebook.

### 5.1 Test Boring Record

Each boring shall be fully described in a Field Test Boring Record. The drilling inspector shall log the boring, as it is being drilled, by recording relevant data on the Boring Record. It may be more appropriate to record the boring information in a bound field log book so that all boring logs recorded (by each drilling inspector) are located in one source. The use of a field log book precludes the possibility of losing individual test boring log sheets. Furthermore, use of the field log book allows for the recording of additional information (i.e. notes) for which space is not allocated on the Field Test Boring Record. Field Test Boring Records may then be transcribed from the field log book, but must be completed at a minimum, on a weekly basis. The Field Test Boring Records must be completely filled out and signed prior to demobilization from the site. Field Test Boring Records must also be legible. Completed Field Test Boring Records shall be converted to report format using a Test Boring Record.

The data which is to be included on the Test Boring Records, when applicable is listed below.

1. Project name, location, and Project and Task Number.
2. Date(s).
3. Identifying number and location of each boring.
4. Soil classifications in accordance with the Unified Soil Classification System (see Section 5.2 and Attachment B). These classifications will be noted in the field by the drilling inspector and revised, if necessary, based on laboratory analysis and review. Both field determined USCS soil classification and a soil description shall be included on the Test Boring Record.
5. Depth limits, and the type and number of samples taken.
6. The number of blows required for each 6-inch penetration of a split-spoon sampler and for each 12-inch penetration of casing. The percentage of sample recovered, hammer weight, fall length, and hydraulic pressures to push thin-walled tubes.
7. Depth to water as first encountered during drilling operations, along with the method of determination. Any distinct water bearing zones shall also be delineated.
8. Loss of drilling fluid (indicative of subsurface voids) and the interval over which it was observed.
9. Identification of equipment used, including model and type of drilling rig, size of split spoon samplers, auger types and sizes, etc.
10. Start date and completion dates for the boring.
11. Name of the drilling company and the driller.
12. Size and length of the casing used in each hole.
13. Observations of visual contamination.
14. Field instrument readings (i.e., photoionization detector, organic vapor analyzer).



TEST BORING RECORD

PROJECT: \_\_\_\_\_ BORING NO.: \_\_\_\_\_  
COORDINATES: EAST: NORTH  
ELEVATION: SURFACE: TOP OF PVC CASING

RIG:					DATE	PROGRESS (FT.)	WEATHER	WATER DEPTH (FT.)	TIME
SIZE (DIAM.)	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

SAMPLE TYPE						DEFINITIONS	
S = Split Spoon      A = Auger T = Shelby Tube      W = Wash R = Air Rotary      C = Core D = Denison      P = Piston N = No Sample						SPT = Standard Penetration Test (ASTM D-1586)(Blows/0.5') RQD = Rock Quality Designation (%) Lab. Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab. Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis	

Depth (ft.)	Samp. Type and No.	Samp. Rec. (ft. & %)	SPT or RQD	Lab Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Match to Sheet 2

DRILLING CO.: BAKER REP.  
DRILLER: BORING NO.

TEST BORING RECORD

PROJECT: \_\_\_\_\_  
BORING NO.: \_\_\_\_\_

SAMPLE TYPE						DEFINITIONS	
S = Split Spoon      A = Auger T = Shelby Tube      W = Wash R = Air Rotary      C = Core D = Denison      P = Piston N = No Sample						SPT = Standard Penetration Test (ASTM D-1586)(Blows/0.5') RQD = Rock Quality Designation (%) Lab. Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab. Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis	
Depth (ft.)	Samp. Type and No.	Samp. Rec. (ft. & %)	SPT or RQD	Lab Class. or Pen. Rate	PID (ppm)	Visual Description	Elevation
11						Continued from Sheet 1	
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DRILLING CO.: \_\_\_\_\_  
DRILLER: \_\_\_\_\_

BAKER REP. \_\_\_\_\_  
BORING NO. \_\_\_\_\_

As the boring is advanced, the inspector shall evaluate the samples and the cuttings to determine the location of each stratigraphic unit. The descriptions should contain color, grain-size distribution, consistency moisture, etc., in addition to the USCS classification category (Section 5.3.7).

Each sample collected for chemical or geotechnical analysis shall be handled as described in SOP F102.

## **5.2     Soil Classification**

The data shall be recorded on a Field Test Boring Record, or in a field logbook. The method of deriving the classification should be described, or reference made to this SOP or other applicable manuals. Both the soil classification and the soil descriptions must be entered on the Field Test Boring Record. If required, the soil classification shall consist of the two-letter USCS classification; the soil description shall be much more detailed.

Where required, soils will be classified according to the USCS. The USCS method of classification is detailed in Attachment B and identifies soil types on the basis of grain-size and liquid limits, and categorizes them through the use of two letters. Although some laboratory testing is required for full USCS classification, preliminary classifications may be made in the field.

Fine-grained soils are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition; peat is designated by "Pt." Coarse-grained soils are divided into sand (S) or gravel (G). The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

The second letter of the two-letter USCS symbol provides information about the grain size distribution of granular soil, or the plasticity characteristics of fine-grained soils. These second letter modifiers are (P) poorly graded/well sorted, (W) well graded/poorly sorted, (C) clayey, (M) silty, (L) low plasticity, or (H) high plasticity.

## **5.3     Soil Descriptions**

The Test Boring Records shall contain complete soil descriptions in addition to the two-letter USCS classification, if required. Soil descriptions include the following components: grain size identification with descriptive terms indicating the relative percentage of each grain size, color, consistency or relative density, moisture content, organic content, plasticity, and other pertinent observations such as visual contamination, HNu measurements, etc. A summary of the soil description components is given in Attachment C.

### 5.3.1 Grain Size Identification

In nature, soils are comprised of varying size, shape, and combinations of the various grain types. The following terms are used to indicate soil grain size:

<u>Size</u>	<u>Size Limits</u>
Cobbles	3-inches to 12-inches
Coarse gravel	3/4-inches to 3-inches
Fine gravel	4.76 mm (# 4 sieve size) to 3/4-inches
Coarse sand	2 mm (# 10 sieve size) to 4.76 mm
Medium sand	0.42 mm (# 40 sieve size) to 2 mm
Fine sand	0.074 mm (# 200 sieve size) to 0.42 mm
Silt	0.002 mm to 0.074 mm
Clay	less than 0.002 mm

The proportion of each grain size (by weight percent) is indicated using the descriptive terms:

Trace	0 to 10 percent
Little	10 to 20 percent
Some	20 to 35 percent
And (or an adjective form of the grain size, i.e., sandy, silty, clayey)	35 to 50 percent

Some examples of soil grain size descriptions are:

- Silty fine sand: 50 to 65 percent fine sand and 35 to 50 percent silt.
- Medium to coarse sand, some silt: 65 to 90 percent medium to coarse sand, 20 to 35 percent silt.
- Fine sandy silt, trace clay: 50 to 65 percent silt, 35 to 50 percent fine sand, and 0 to 10 percent clay.

The soil type may be classified as noncohesive, granular soils or as cohesive, fine-grained soils as discussed in Section 5.3.3. The grain shape of a soil usually does not need to be determined unless unusual or unique features are readily apparent.

### 5.3.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light-gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent between borings.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors because sampling devices tend to smear the sample surface creating color variations between interior and exterior.

The term "mottled" shall be used to indicate soil irregularly marked with spots of different colors. Soil color charts shall not be used unless specified by the Project Manager.

### 5.3.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the drilling inspector first shall identify the soil type. Granular soils contain predominantly sands and gravels. These types of soil are noncohesive (particles do not adhere well when compressed). Conversely, fine-grained soils which contain predominantly silts and clays are cohesive (particles will adhere when compressed).

The density of noncohesive, granular soils or the consistency of cohesive soils is classified according to standard penetration resistances obtained from split-spoon (split-barrel) sampling performed according to ASTM D-1586. Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12-inches into the material using a 140-pound hammer falling freely through 30-inches. In cases where geotechnical information is required, the standard penetration test is performed by driving the sampler through an 18-inch sample interval, the number of blows will then be recorded for each six-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of the sample interval. It is important to note that if gravel and rock fragments are broken by the sampler, or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This must be noted on the Field Test Boring Record and referenced to the sample number. In cases where soil sampling for environmental analytical analysis is required, 24-inch spoon barrels can be used in order to obtain a sufficient quantity of sample for required analysis. Accordingly, the second and third 6-inch increments will be used to calculate the relative density.

The relative density designations for noncohesive soils are:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very loose	Less than 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	Greater than 50

The consistency of cohesive soils is also determined by blow counts as shown:

<u>Designation</u>	<u>Standard Penetration Resistance (Blows per Foot)</u>
Very Soft	Less than 2
Soft	2 to 4
Medium Stiff	4 to 8
Stiff	8 to 15
Very Stiff	15 to 30
Hard	Over 30

#### 5.3.4 Moisture Content

Moisture content is estimated in the field according to four categories: dry, damp, moist, and wet:

<u>Designation</u>	<u>Moisture Content</u>
Dry	0 to 10 percent
Damp	10 to 20 percent
Moist	20 to 35 percent
Wet	35 to 50 percent

Little or no water should appear in dry soil. Wet soils appear to contain all the water they can possibly hold (i.e., saturated). Damp and moist are subjective. Laboratory analysis should be performed if it is necessary to accurately determine the natural water content.

#### 5.3.5 Stratification

Stratification can only be determined after the split-barrel sampler is opened. Typically, bedding thicknesses are described as follows:

<u>Designation</u>	<u>Bedding Spacing</u>
Indistinct	No bedding apparent
Laminated	Less than 1/2-inch
Very thin	1/2-inch to 1-inch
Thin	1-inch to 4-inches
Medium	4-inches to 1-foot
Thick	1-foot to 3-feet
Massive	Greater than three feet



### **5.3.6 Texture/Fabric/Bedding**

The texture/fabric/bedding of a soil shall be described, where appropriate. Texture is described as the relative angularity of the soil particles: rounded, subrounded, subangular, angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation or orientation. The bedding structure also shall be noted (e.g., stratified, lensatic, nonstratified, heterogeneous varved, etc.).

### **5.3.7 Summary of Soil Descriptions**

In summary, soils shall be classified in a similar manner by each drilling inspector. The soil description shall include:

- Soil grain size with appropriate descriptors
- Color
- Relative density and/or consistency
- Moisture content
- Stratification
- Texture/fabric/bedding
- Other distinguishing features

These descriptors are evaluated and the soil classified according to the USCS. All information, measurements and observations shall be legibly recorded on a Field Test Boring Record.

## **5.4 Sedimentary Rock Classifications**

Rocks are grouped into three main divisions: sedimentary, igneous, and metamorphic. Sedimentary rocks are the most predominant type exposed at the earth's surface. As such, this section will consider only classification of sedimentary rocks. Standard geologic references should be used for the complete classification of sedimentary, igneous and metamorphic rocks.

For the purpose of completing the Field Test Boring Record in the field, sedimentary rocks should be classified using the following hierarchy:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Rock Quality Designation
- Weathering
- Other characteristics

#### 5.4.1 Rock Type

There are numerous types of sedimentary rocks such as sandstone, shale, siltstone, claystone, conglomerate, limestone, dolomite, coal, etc. The drilling inspector should select the most appropriate rock type based on experience. Some of the references listed in Section 7.0 provide a more complete discussion of sedimentary rock types.

In addition to selecting a rock type, the drilling inspector should record the grain size (and composition of grains and cement, if apparent) on the Field Test Boring Record. The following designation should be used to describe grain size in sedimentary rocks:

<u>Designation</u>	<u>Grain Size Diameter</u>
Cobbles	Greater than 64 mm (2.5-inches)
Pebbles	4 mm (0.16-inches) to 64 mm
Granules	2 mm (0.08-inches) to 4 mm
Very Coarse Sand	1 mm to 2 mm
Coarse Sand	0.5 mm to 1 mm
Medium Sand	0.25 mm to 0.5 mm
Fine Sand	0.125 mm to 0.25 mm
Very Fine Sand	0.0625 mm to 0.125 mm
Silt	0.0039 mm to 0.0625 mm
Clay	Smaller than 0.0039 mm

For individual boundaries of grain size, a scale can be used for coarse-grained rocks. However, the division between silt and clay likely will not be measurable in the field. This boundary shall be determined by use of a hand lens. If the grains cannot be seen with the unaided eye, but are distinguishable with a hand lens (5x magnification) the sample is silt. If the grains are not distinguishable with a hand lens, the sample is clay.

#### 5.4.2 Color

The color of rock can be determined in a manner similar to that for soil samples. Rock cores or fragments shall be classified while wet, when possible. Rock color charts shall not be used unless specified by the Project Manager.

#### 5.4.3 Bedding Thickness

The bedding thickness designation for soils (Section 5.3.5) shall also be used for rock descriptions.

#### 5.4.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness follows:

- Very Soft – Very soft indicates that the rock is easily gouged by a knife, easily scratched by a fingernail, and/or easily broken by hand
- Soft – Soft indicates that the rock may be gouged by a knife, scratched by a fingernail, difficult to break by hand, and/or powders when hit by a hammer.
- Medium Hard – Medium hard indicates that the rock is easily scratched by a knife and/or is easily broken when hit by a hammer.
- Hard – Hard indicates that the rock is difficult to scratch with a knife but may be broken with a hammer.
- Very Hard – Very hard indicates that the rock is difficult to break with a hammer.

Note the difference in usage between the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock while a gouge is much deeper.

#### 5.4.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is measured and is described by the following terms:

- Very Broken – Less than a 2-inch spacing between fractures
- Broken – A 2-inch to 1-foot spacing between fractures
- Blocky – A 1-foot to 3-foot spacing between fractures
- Massive – A 3-foot to 10-foot spacing between fractures

#### 5.4.6 Rock Quality Designation

The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding four inches and dividing by the total length of core run:

$$RQD (\%) = r/l \times 100$$

Where:

$r$  = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches, and have resulted from natural breaks. Natural breaks include slickenslides, joints, compaction slicks, bedding plane partings (not caused by drilling) friable zones, etc.

$l$  = Total length of core run.

The results of the RQD calculations shall be recorded on the Field Test Boring Record.

#### 5.4.7 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and also is useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Decomposed – Soft to very soft, bedding and fractures indistinct, no cementation.
- Highly weathered – very soft to soft, with medium hard relic rock fragments, little to moderate cementation. Vugs and openings in bedding and fracture planes, some of which may be filled.
- Weathered – Soft to medium hard. Good cementation, bedding and fractures are pronounced. Uniformly stained.
- Slightly weathered – Medium hard. Fractures pronounced, nonuniform staining, bedding distinct.
- Fresh – Medium hard to hard. No staining. Fractures may be present, bedding may or may not be distinct.

#### 5.4.8 Other Characteristics

The following items should be included in rock description, where applicable:

- Description of contacts between rock units (sharp or gradational)
- Stratification
- Description of any filled cavities
- Cementation (calcareous, siliceous, hematitic, etc.)
- Description of joints and open fractures (with strike and dip, if possible)
- Observation of the presence of fossils

#### 5.4.9 Additional Terms

The following terms also are used to further identify rocks:

- Seam - thin (12-inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of an accessory material.
- Few - Indicates insignificant (0 to 15 percent) amounts of an accessory material.
- Interbedded - Indicates thin or very thin alternating seams of material occurring in approximately equal amounts.
- Interlayered - Indicates thick alternating seams of material occurring in approximately equal amounts.

#### 6.0 QUALITY ASSURANCE RECORDS

Quality Assurance Records shall consist of completed Field Test Boring Records and Test Boring Records.

#### 7.0 REFERENCES

1. American Society for Testing and Materials, 1990. Standard Methods for Classification of Soils for Engineering Purposes. ASTM Method D2487-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.
2. American Society for Testing and Materials, 1990. Standard Practice for Description and Identification of Soils (Visual - Manual Procedure). ASTM Method D2488-90, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

**ATTACHMENT A**  
**EXAMPLE TEST BORING RECORD**

BAKER		TEST BORING LOG				BOREHOLE NUMBER: 17-SB01		SHEET: 1 OF 1				
PROJECT NUMBER: PROJECT NAME: LOCATION: DRILLING COMPANY: ROCK-RAY DRILLING, INC. RIG TYPE & NUMBER: TRUCK RIG MOBILE B-45 DRILLING METHOD: HOLLOW STEM AUGERS WEATHER: SUNNY, MILD GEOLOGIST: E J. KLEINKAUF ENV. SCIENTIST: G H. BUCHHOLZ DATE BEGUN: 03/11/97 DATE COMPLETED: 03/11/97						GROUND SURFACE ELEVATION: 8.60' msl TOTAL DEPTH: 16.00' bgs						
ELEVATION	DEPTH	SOIL SAMPLES	SAMPLE NO	SAMPLE METHOD	BLOWS/6"	RECOVERY	PI0 (PPM)		LITHOLOGY	DESCRIPTION	DEPTH	
							B6	P3				
8.00	0.0									ASPHALT AND STONE	0.0	
7.00	1.0		S-1	SS	11	1.00	0.0	0.0		SAND: Fine to coarse grained, little	1.0	
6.00	2.0		S-2	SS	3	2.00	0.0	0.0		Fine rock fragments, little clayey silt/silt, black/brown/light brown, moist, loose (Fill)	2.0	
5.00	3.0				2						3.0	
4.00	4.0		S-3	SS	1	0.17	0.0	0.0		SAND: fine to medium grained, some clayey silt, gray	4.0	
3.00	5.0				1						5.0	
2.00	6.0		S-4	SS	1	1.50	0.0	0.0		SAND: Fine to medium grained, little clayey silt, brown	6.0	
1.00	7.0				1						7.0	
0.00	8.0		S-5	SS	1	1.67	0.0	0.0		SAND: Fine to medium grained, little silt, brown/light brown	8.0	
-1.00	9.0				2						9.0	
-2.00	10.0		S-6	SS	1	2.00	0.0	0.0			10.0	
-3.00	11.0				1						11.0	
-4.00	12.0		S-7	SS	1	2.00	0.0	0.0		SILT AND CLAY: some Fine to medium grained sand, gray	12.0	
-5.00	13.0				1						13.0	
-6.00	14.0		S-8	SS	NOV 12"	2.00	0.0	0.0			14.0	
-7.00	15.0				3						15.0	
-8.00	16.0				3						16.0	
-9.00	17.0		BOTTOM OF BOREHOLE = 16.0' NOTES: 1) Groundwater encountered at 3' during drilling									17.0
-10.00	18.0											18.0
-11.00	19.0											19.0
-12.00	20.0											20.0
-13.00	21.0											21.0
-14.00	22.0											22.0
-15.00	23.0											23.0
-16.00	24.0											24.0
-17.00	25.0											25.0
-18.00	26.0											26.0
-19.00	27.0											27.0
-20.00	28.0											28.0

**ATTACHMENT B**  
**UNIFIED SOIL CLASSIFICATION SYSTEM**





## Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>1</sup>

This standard is issued under the fixed designation D 2487; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DOD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

### 1. Scope

1.1 This standard describes a system for classifying mineral and organo-mineral soils for engineering purposes based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index and shall be used when precise classification is required.

NOTE 1—Use of this standard will result in a single classification group symbol and group name except when a soil contains 5 to 12 % fines or when the plot of the liquid limit and plasticity index values falls into the crosshatched area of the plasticity chart. In these two cases, a dual symbol is used, for example, GP-GM, CL-ML. When the laboratory test results indicate that the soil is close to another soil classification group, the borderline condition can be indicated with two symbols separated by a slash. The first symbol should be the one based on this standard, for example, CL/CH, GM/SM, SC/CL. Borderline symbols are particularly useful when the liquid limit value of clayey soils is close to 50. These soils can have expansive characteristics and the use of a borderline symbol (CL/CH, CH/CL) will alert the user of the assigned classifications of expansive potential.

1.2 The group symbol portion of this system is based on laboratory tests performed on the portion of a soil sample passing the 3-in. (75-mm) sieve (see Specification E 11).

1.3 As a classification system, this standard is limited to naturally occurring soils.

NOTE 2—The group names and symbols used in this test method may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. See Appendix X2.

1.4 This standard is for qualitative application only.

NOTE 3—When quantitative information is required for detailed designs of important structures, this test method must be supplemented by laboratory tests or other quantitative data to determine performance characteristics under expected field conditions.

1.5 This standard is the ASTM version of the Unified Soil Classification System. The basis for the classification scheme is the Airfield Classification System developed by A. Casagrande in the early 1940's.<sup>2</sup> It became known as the Unified Soil Classification System when several U.S. Government Agencies adopted a modified version of the Airfield System in 1952.

1.6 *This standard does not purport to address all of the*

*safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

- C 117 Test Method for Materials Finer Than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing<sup>3</sup>
- C 136 Method for Sieve Analysis of Fine and Coarse Aggregates<sup>3</sup>
- C 702 Practice for Reducing Field Samples of Aggregate to Testing Size<sup>3</sup>
- D 420 Guide for Investigating and Sampling Soil and Rock<sup>4</sup>
- D 421 Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>4</sup>
- D 422 Test Method for Particle-Size Analysis of Soils<sup>4</sup>
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>4</sup>
- D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75- $\mu$ m) Sieve<sup>4</sup>
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock<sup>4</sup>
- D 2217 Practice for Wet Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants<sup>4</sup>
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>4</sup>
- D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)<sup>4</sup>
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils<sup>4</sup>
- D 4427 Classification of Peat Samples by Laboratory Testing<sup>4</sup>
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes<sup>3</sup>

### 3. Terminology

3.1 **Definitions**—Except as listed below, all definitions are in accordance with Terminology D 653.

<sup>1</sup> This standard is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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<sup>2</sup> Casagrande, A., "Classification and Identification of Soils," *Transactions*, ASCE, 1948, p. 901.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 04.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 04.08.

NOTE 4—For particles retained on a 3-in. (75-mm) U.S. standard sieve, the following definitions are suggested:

—*Cobbles*—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) U.S. standard sieve, and

—*Boulders*—particles of rock that will not pass a 12-in. (300-mm) square opening

3.1.1 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) U.S. standard sieve with the following subdivisions:

—*Coarse*—passes 3-in. (75-mm) sieve and retained on ¾-in. (19-mm) sieve, and

—*Fine*—passes ¾-in. (19-mm) sieve and retained on No. 4 (4.75-mm) sieve.

3.1.2 *sand*—particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-μm) U.S. standard sieve with the following subdivisions:

—*Coarse*—passes No. 4 (4.75-mm) sieve and retained on No. 10 (2.00-mm) sieve,

—*Medium*—passes No. 10 (2.00-mm) sieve and retained on No. 40 (425-μm) sieve, and

—*Fine*—passes No. 40 (425-μm) sieve and retained on No. 200 (75-μm) sieve.

3.1.3 *clay*—soil passing a No. 200 (75-μm) U.S. standard sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the “A” line.

3.1.4 *silt*—soil passing a No. 200 (75-μm) U.S. standard sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4 or if the plot of plasticity index versus liquid limit falls below the “A” line.

3.1.5 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.6 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.7 *peat*—a soil composed of vegetable tissue in various stages of decomposition usually with an organic odor, a dark-brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

## 3.2 Descriptions of Terms Specific to This Standard:

3.2.1 *coefficient of curvature*,  $C_c$ —the ratio  $(D_{30})^2/(D_{10} \times D_{60})$ , where  $D_{60}$ ,  $D_{30}$ , and  $D_{10}$  are the particle diameters corresponding to 60, 30, and 10 % finer on the cumulative particle-size distribution curve, respectively.

3.2.2 *coefficient of uniformity*,  $C_u$ —the ratio  $D_{60}/D_{10}$ , where  $D_{60}$  and  $D_{10}$  are the particle diameters corresponding to 60 and 10 % finer on the cumulative particle-size distribution curve, respectively.

## 4. Summary

4.1 As illustrated in Table 1, this classification system identifies three major soil divisions: coarse-grained soils, fine-grained soils, and highly organic soils. These three divisions are further subdivided into a total of 15 basic soil groups.

4.2 Based on the results of visual observations and prescribed laboratory tests, a soil is catalogued according to the basic soil groups, assigned a group symbol(s) and name, and thereby classified. The flow charts, Fig. 1 for fine-grained soils, and Fig. 2 for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name.

## 5. Significance and Use

5.1 This standard classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

5.2 The assigning of a group name and symbol(s) along with the descriptive information required in Practice D 2488 can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.3 The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This standard provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

5.4 This standard may also be used as an aid in training personnel in the use of Practice D 2488.

5.5 This standard may be used in combination with Practice D 4083 when working with frozen soils.

## 6. Apparatus

6.1 In addition to the apparatus that may be required for obtaining and preparing the samples and conducting the prescribed laboratory tests, a plasticity chart, similar to Fig. 3, and a cumulative particle-size distribution curve, similar to Fig. 4, are required.

NOTE 5—The “U” line shown on Fig. 3 has been empirically determined to be the approximate “upper limit” for natural soils. It is a good check against erroneous data, and any test results that plot above or to the left of it should be verified.

## 7. Sampling

7.1 Samples shall be obtained and identified in accordance with a method or methods, recommended in Recommended Guide D 420 or by other accepted procedures.

7.2 For accurate identification, the minimum amount of test sample required for this test method will depend on which of the laboratory tests need to be performed. Where only the particle-size analysis of the sample is required, specimens having the following minimum dry weights are required:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (¾ in.)	200 g (0.5 lb)
19.0 mm (¾ in.)	1.0 kg (2.2 lb)
38.1 mm (1½ in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

Whenever possible, the field samples should have weights two to four times larger than shown.

TABLE 1 Soil Classification Chart

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>A</sup>				Soil Classification	
				Group Symbol	Group Name <sup>B</sup>
COARSE-GRAINED SOILS More than 50 % retained on No. 200 sieve	Gravels More than 50 % of coarse fraction retained on No. 4 sieve	Clean Gravels Less than 5 % fines <sup>C</sup>	$Cu \geq 4$ and $1 \leq Cc \leq 3^E$	GW	Well-graded gravel <sup>F</sup>
			$Cu < 4$ and/or $1 > Cc > 3^E$	GP	Poorly graded gravel <sup>F</sup>
		Gravels with Fines More than 12 % fines <sup>C</sup>	Fines classify as ML or MH	GM	Silty gravel <sup>F,G,H</sup>
			Fines classify as CL or CH	GC	Clayey gravel <sup>F,G,H</sup>
	Sands 50 % or more of coarse fraction passes No. 4 sieve	Clean Sands Less than 5 % fines <sup>D</sup>	$Cu \geq 6$ and $1 \leq Cc \leq 3^E$	SW	Well-graded sand <sup>I</sup>
			$Cu < 6$ and/or $1 > Cc > 3^E$	SP	Poorly graded sand <sup>I</sup>
		Sands with Fines More than 12 % fines <sup>D</sup>	Fines classify as ML or MH	SM	Silty sand <sup>G,H,I</sup>
			Fines classify as CL or CH	SC	Clayey sand <sup>G,H,I</sup>
FINE-GRAINED SOILS 50 % or more passes the No. 200 sieve	Silt and Clays Liquid limit less than 50	inorganic	$PI > 7$ and plots on or above "A" line <sup>J</sup>	CL	Lean clay <sup>K,L,M</sup>
			$PI < 4$ or plots below "A" line <sup>J</sup>	ML	Silt <sup>K,L,M</sup>
		organic	Liquid limit – oven dried Liquid limit – not dried $< 0.75$	OL	Organic clay <sup>K,L,M,N</sup> Organic silt <sup>K,L,M,O</sup>
	Silt and Clays Liquid limit 50 or more	inorganic	$PI$ plots on or above "A" line	CH	Fat clay <sup>K,L,M</sup>
			$PI$ plots below "A" line	MH	Elastic silt <sup>K,L,M</sup>
		organic	Liquid limit – oven dried Liquid limit – not dried $< 0.75$	OH	Organic clay <sup>K,L,M,P</sup> Organic silt <sup>K,L,M,O</sup>
HIGHLY ORGANIC SOILS	Primarily organic matter, dark in color, and organic odor			PT	Peat

<sup>A</sup> Based on the material passing the 3-in. (75-mm) sieve.

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> Gravels with 5 to 12 % fines require dual symbols:  
GW-GM well-graded gravel with silt  
GW-GC well-graded gravel with clay  
GP-GM poorly graded gravel with silt  
GP-GC poorly graded gravel with clay

<sup>D</sup> Sands with 5 to 12 % fines require dual symbols:  
SW-SM well-graded sand with silt  
SW-SC well-graded sand with clay  
SP-SM poorly graded sand with silt  
SP-SC poorly graded sand with clay

$E \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

<sup>F</sup> If soil contains  $\geq 15$  % sand, add "with sand" to group name.

<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>H</sup> If fines are organic, add "with organic fines" to group name.

<sup>I</sup> If soil contains  $\geq 15$  % gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly sand, add "sandy" to group name.

<sup>M</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup>  $PI < 4$  or plots below "A" line.

<sup>P</sup>  $PI$  plots on or above "A" line.

<sup>Q</sup>  $PI$  plots below "A" line.

<sup>A</sup> Based on the material passing the 3-in. (75-mm) sieve.

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> Gravels with 5 to 12 % fines require dual symbols:

GW-GM well-graded gravel with silt  
GW-GC well-graded gravel with clay  
GP-GM poorly graded gravel with silt  
GP-GC poorly graded gravel with clay

<sup>D</sup> Sands with 5 to 12 % fines require dual symbols:

SW-SM well-graded sand with silt  
SW-SC well-graded sand with clay  
SP-SM poorly graded sand with silt  
SP-SC poorly graded sand with clay

$$E \quad Cu = D_{60}/D_{10} \quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$$

<sup>F</sup> If soil contains  $\geq 15$  % sand, add "with sand" to group name.

<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>H</sup> If fines are organic, add "with organic fines" to group name.

<sup>I</sup> If soil contains  $\geq 15$  % gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in hatched area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29 % plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly sand, add "sandy" to group name.

<sup>M</sup> If soil contains  $\geq 30$  % plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup>  $PI < 4$  or plots below "A" line.

<sup>P</sup>  $PI$  plots on or above "A" line.

<sup>Q</sup>  $PI$  plots below "A" line.

7.3 When the liquid and plastic limit tests must also be performed, additional material will be required sufficient to provide 150 g to 200 g of soil finer than the No. 40 (425- $\mu$ m) sieve.

7.4 If the field sample or test specimen is smaller than the minimum recommended amount, the report shall include an appropriate remark.

## 8. Classification of Peat

8.1 A sample composed primarily of vegetable tissue in various stages of decomposition and has a fibrous to amorphous texture, a dark-brown to black color, and an organic odor should be designated as a highly organic soil and shall be classified as peat, PT, and not subjected to the classification procedures described hereafter.

8.2 If desired, classification of type of peat can be performed in accordance with Classification D 4427.

## 9. Preparation for Classification

9.1 Before a soil can be classified according to this standard, generally the particle-size distribution of the minus 3-in. (75-mm) material and the plasticity characteristics of the minus No. 40 (425- $\mu$ m) sieve material must be deter-

mined. See 9.8 for the specific required tests.

9.2 The preparation of the soil specimen(s) and the testing for particle-size distribution and liquid limit and plasticity index shall be in accordance with accepted standard procedures. Two procedures for preparation of the soil specimens for testing for soil classification purposes are given in Appendixes X3 and X4. Appendix X3 describes the wet preparation method and is the preferred method for cohesive soils that have never dried out and for organic soils.

9.3 When reporting soil classifications determined by this standard, the preparation and test procedures used shall be reported or referenced.

9.4 Although the test procedure used in determining the particle-size distribution or other considerations may require a hydrometer analysis of the material, a hydrometer analysis is not necessary for soil classification.

9.5 The percentage (by dry weight) of any plus 3-in. (75-mm) material must be determined and reported as auxiliary information.

9.6 The maximum particle size shall be determined (measured or estimated) and reported as auxiliary information.

9.7 When the cumulative particle-size distribution is required, a set of sieves shall be used which include the

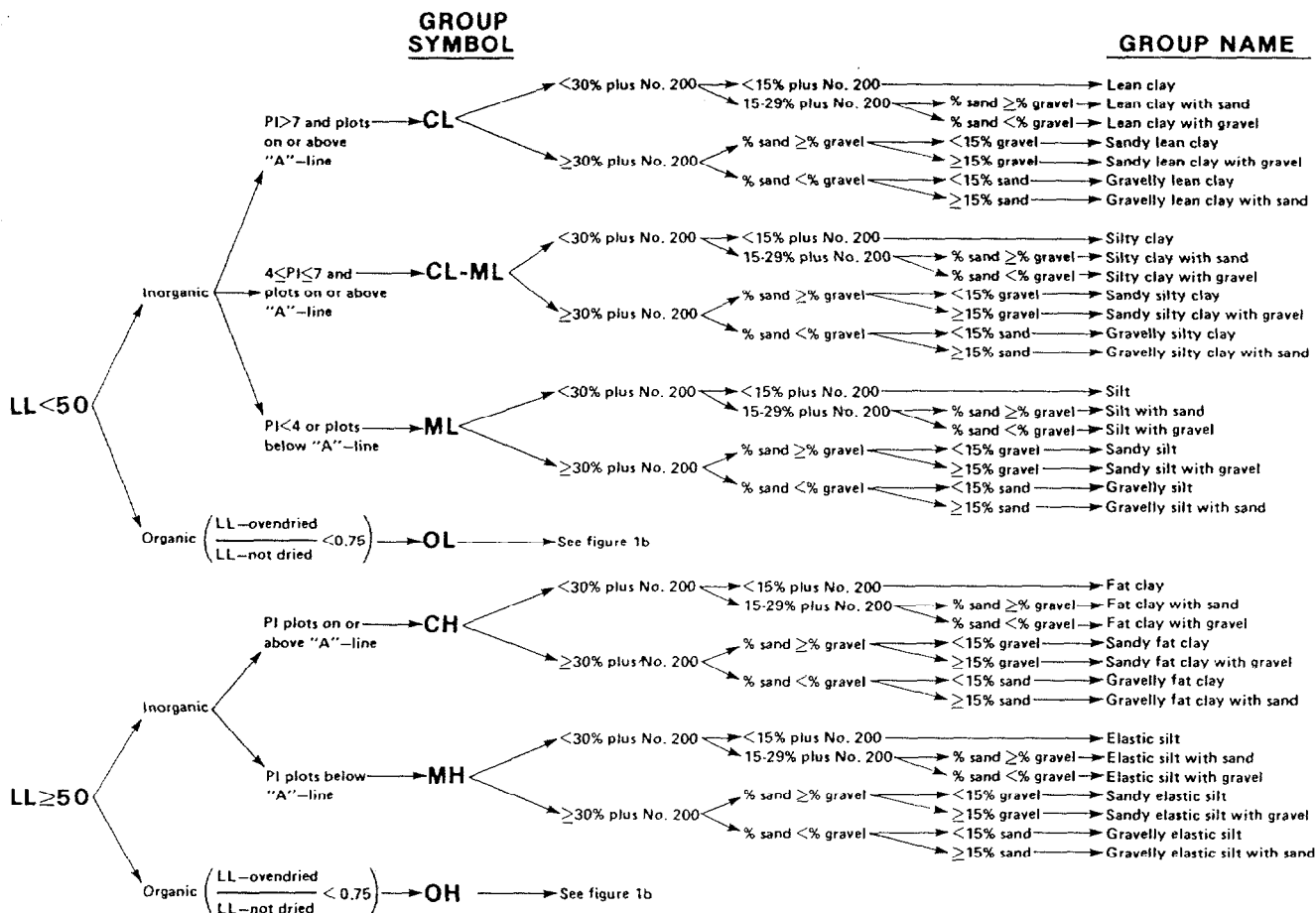


FIG. 1a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

following sizes (with the largest size commensurate with the maximum particle size) with other sieve sizes as needed or required to define the particle-size distribution:

- 3-in. (75-mm)
- ¾-in. (19.0-mm)
- No. 4 (4.75-mm)
- No. 10 (2.00-mm)
- No. 40 (425-µm)
- No. 200 (75-µm)

9.8 The tests required to be performed in preparation for classification are as follows:

9.8.1 For soils estimated to contain less than 5 % fines, a plot of the cumulative particle-size distribution curve of the fraction coarser than the No. 200 (75-µm) sieve is required. The cumulative particle-size distribution curve may be plotted on a graph similar to that shown in Fig. 4.

9.8.2 For soils estimated to contain 5 to 15 % fines, a cumulative particle-size distribution curve, as described in 9.8.1, is required, and the liquid limit and plasticity index are required.

9.8.2.1 If sufficient material is not available to determine the liquid limit and plasticity index, the fines should be estimated to be either silty or clayey using the procedures described in Practice D 2488 and so noted in the report.

9.8.3 For soils estimated to contain 15 % or more fines, a determination of the percent fines, percent sand, and percent gravel is required, and the liquid limit and plasticity index

are required. For soils estimated to contain 90 % fines or more, the percent fines, percent sand, and percent gravel may be estimated using the procedures described in Practice D 2488 and so noted in the report.

## 10. Preliminary Classification Procedure

10.1 Class the soil as fine-grained if 50 % or more by dry weight of the test specimen passes the No. 200 (75-µm) sieve and follow Section 11.

10.2 Class the soil as coarse-grained if more than 50 % by dry weight of the test specimen is retained on the No. 200 (75-µm) sieve and follow Section 12.

## 11. Procedure for Classification of Fine-Grained Soils (50 % or more by dry weight passing the No. 200 (75-µm) sieve)

11.1 The soil is an inorganic clay if the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line, the plasticity index is greater than 4, and the presence of organic matter does not influence the liquid limit as determined in 11.3.2.

NOTE 6—The plasticity index and liquid limit are determined on the minus No. 40 (425 µm) sieve material.

11.1.1 Classify the soil as a *lean clay*, CL, if the liquid limit is less than 50. See area identified as CL on Fig. 3.

11.1.2 Classify the soil as a *fat clay*, CH, if the liquid limit

GROUP SYMBOL

GROUP NAME

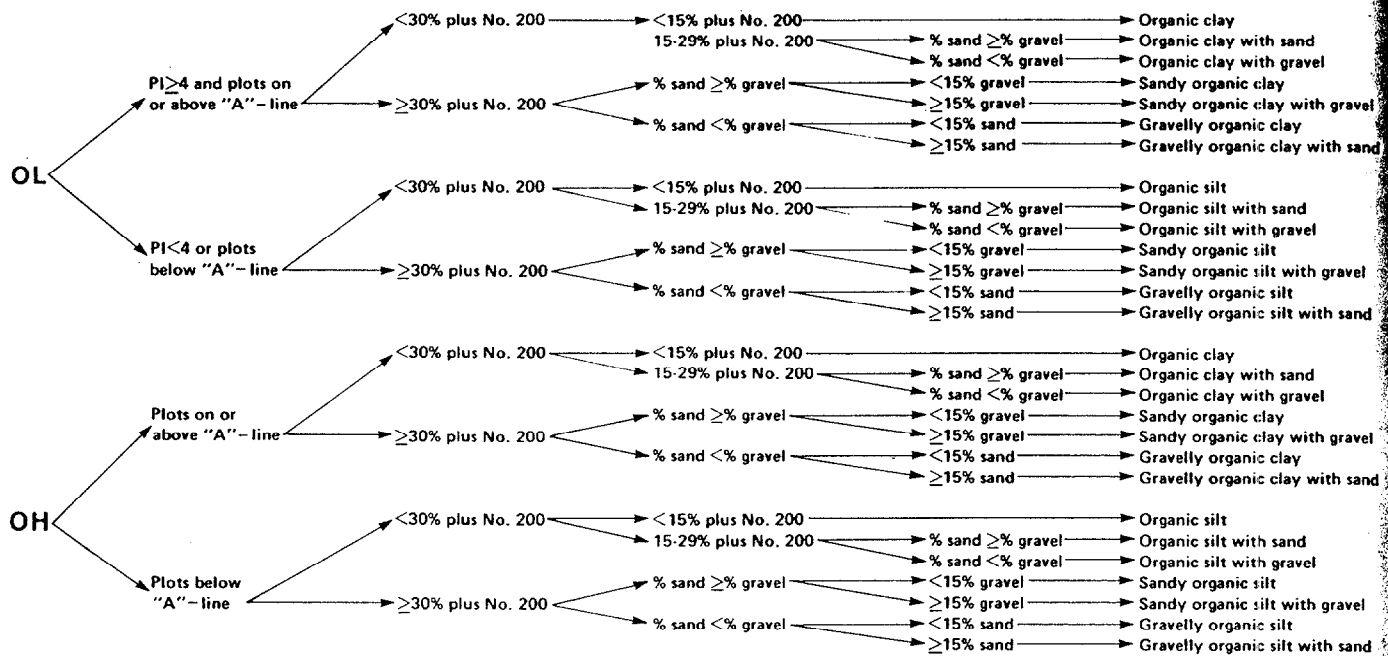


FIG. 1b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

GROUP SYMBOL

GROUP NAME

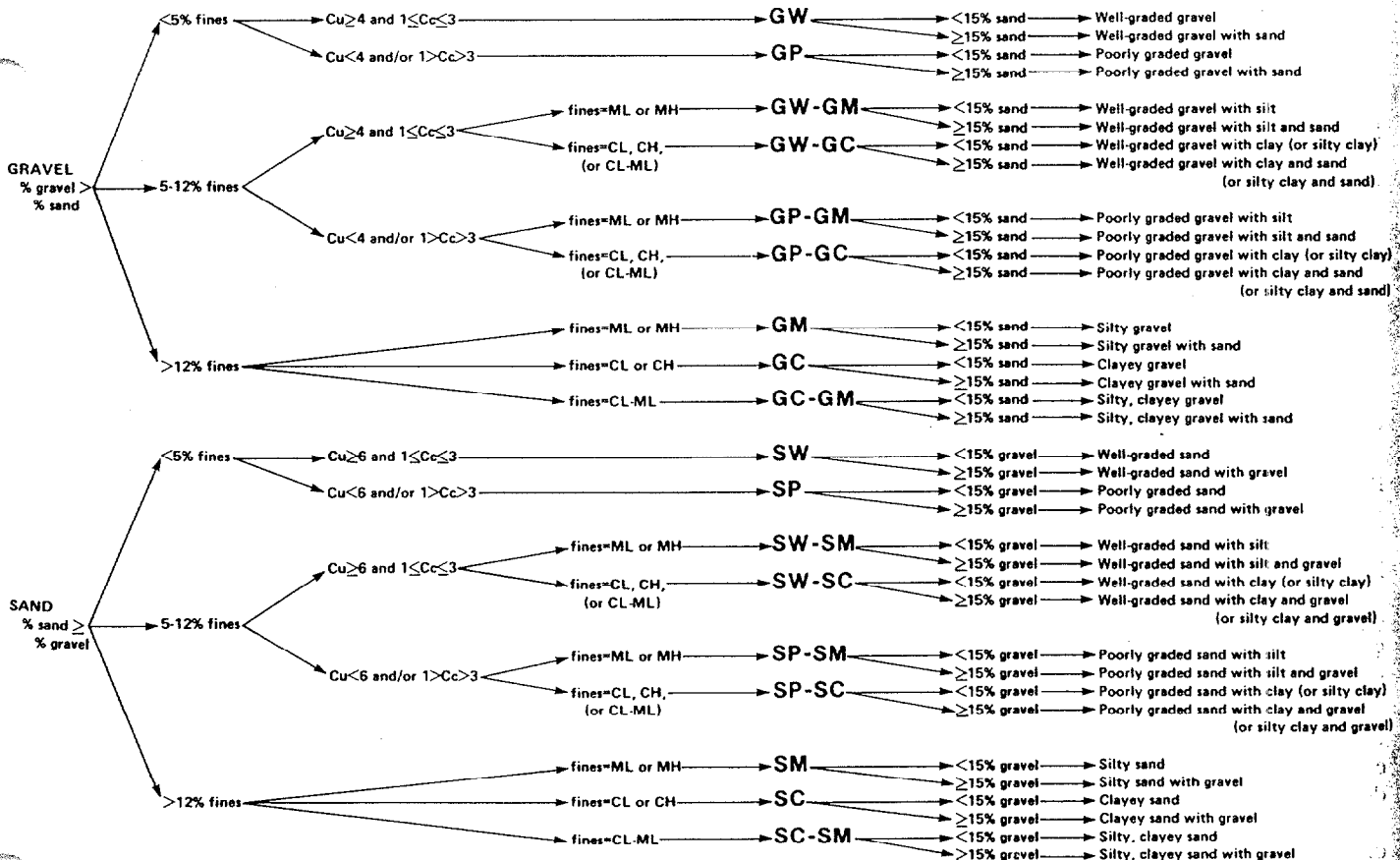


FIG. 2 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)

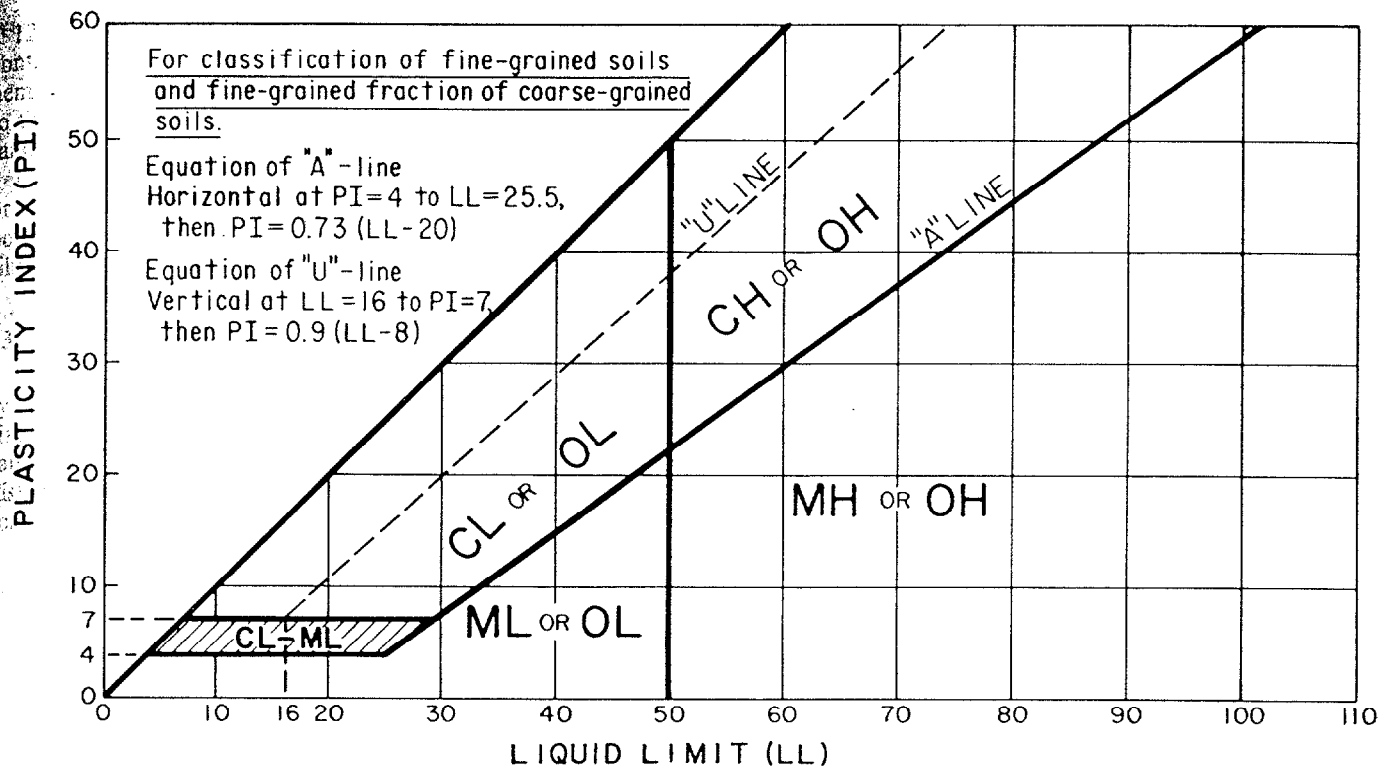


FIG. 3 Plasticity Chart

is 50 or greater. See area identified as CH on Fig. 3.

NOTE 7—In cases where the liquid limit exceeds 110 or the plasticity index exceeds 60, the plasticity chart may be expanded by maintaining the same scale on both axes and extending the "A" line at the indicated slope.

11.1.3 Classify the soil as a *silty clay*, CL-ML, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line and the plasticity index is in the range of 4 to 7. See area identified as CL-ML on Fig. 3.

11.2 The soil is an inorganic silt if the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4, and presence of organic matter does not influence the liquid limit as determined in 11.3.2.

11.2.1 Classify the soil as a *silt*, ML, if the liquid limit is less than 50. See area identified as ML on Fig. 3.

11.2.2 Classify the soil as an *elastic silt*, MH, if the liquid limit is 50 or greater. See area identified as MH on Fig. 3.

11.3 The soil is an organic silt or clay if organic matter is present in sufficient amounts to influence the liquid limit as determined in 11.3.2.

11.3.1 If the soil has a dark color and an organic odor when moist and warm, a second liquid limit test shall be performed on a test specimen which has been oven dried at  $110 \pm 5^\circ\text{C}$  to a constant weight, typically over night.

11.3.2 The soil is an organic silt or organic clay if the liquid limit after oven drying is less than 75 % of the liquid limit of the original specimen determined before oven drying (see Procedure B of Practice D 2217).

11.3.3 Classify the soil as an *organic silt* or *organic clay*, OL, if the liquid limit (not oven dried) is less than 50 %.

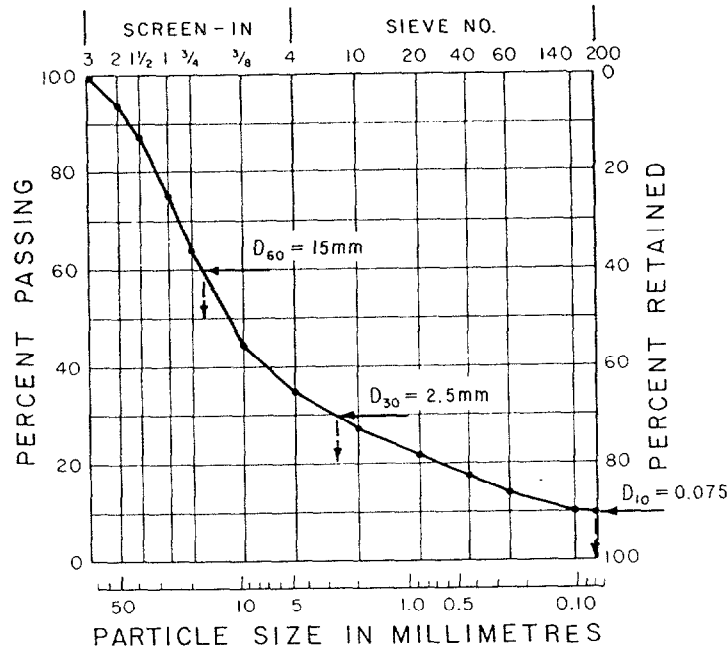
Classify the soil as an *organic silt*, OL, if the plasticity index is less than 4, or the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OL, if the plasticity index is 4 or greater and the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OL (or CL-ML) on Fig. 3.

11.3.4 Classify the soil as an *organic clay* or *organic silt*, OH, if the liquid limit (not oven dried) is 50 or greater. Classify the soil as an *organic silt*, OH, if the position of the plasticity index versus liquid limit plot falls below the "A" line. Classify the soil as an *organic clay*, OH, if the position of the plasticity index versus liquid limit plot falls on or above the "A" line. See area identified as OH on Fig. 3.

11.4 If less than 30 % but 15 % or more of the test specimen is retained on the No. 200 (75- $\mu\text{m}$ ) sieve, the words "with sand" or "with gravel" (whichever is predominant) shall be added to the group name. For example, lean clay with sand, CL; silt with gravel, ML. If the percent of sand is equal to the percent of gravel, use "with sand."

11.5 If 30 % or more of the test specimen is retained on the No. 200 (75- $\mu\text{m}$ ) sieve, the words "sandy" or "gravelly" shall be added to the group name. Add the word "sandy" if 30 % or more of the test specimen is retained on the No. 200 (75- $\mu\text{m}$ ) sieve and the coarse-grained portion is predominantly sand. Add the word "gravelly" if 30 % or more of the test specimen is retained on the No. 200 (75- $\mu\text{m}$ ) sieve and the coarse-grained portion is predominantly gravel. For example, sandy lean clay, CL; gravelly fat clay, CH; sandy silt, ML. If the percent of sand is equal to the percent of gravel, use "sandy."

# SIEVE ANALYSIS



$$C_u = \frac{D_{60}}{D_{10}} = \frac{15}{0.075} = 200 \quad C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} = \frac{(2.5)^2}{0.075 \times 15} = 5.6$$

FIG. 4 Cumulative Particle-Size Plot

## 12. Procedure for Classification of Coarse-Grained Soils (more than 50 % retained on the No. 200 (75-μm) sieve)

12.1 Class the soil as gravel if more than 50 % of the coarse fraction [plus No. 200 (75-μm) sieve] is retained on the No. 4 (4.75-mm) sieve.

12.2 Class the soil as sand if 50 % or more of the coarse fraction [plus No. 200 (75-μm) sieve] passes the No. 4 (4.75-mm) sieve.

12.3 If 12 % or less of the test specimen passes the No. 200 (75-μm) sieve, plot the cumulative particle-size distribution, Fig. 4, and compute the coefficient of uniformity,  $C_u$ , and coefficient of curvature,  $C_c$ , as given in Eqs 1 and 2.

$$C_u = D_{60}/D_{10} \quad (1)$$

$$C_c = (D_{30})^2/(D_{10} \times D_{60}) \quad (2)$$

where:

$D_{10}$ ,  $D_{30}$ , and  $D_{60}$  = the particle-size diameters corresponding to 10, 30, and 60 %, respectively, passing on the cumulative particle-size distribution curve, Fig. 4.

NOTE 8—It may be necessary to extrapolate the curve to obtain the  $D_{10}$  diameter.

12.3.1 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as a *well-graded gravel*, GW, or *well-graded sand*, SW, if  $C_u$  is greater than 4.0 for gravel or greater than 6.0 for sand, and  $C_c$  is at least 1.0 but not more than 3.0.

12.3.2 If less than 5 % of the test specimen passes the No. 200 (75-μm) sieve, classify the soil as *poorly graded gravel*, GP, or *poorly graded sand*, SP, if either the  $C_u$  or the  $C_c$  criteria for well-graded soils are not satisfied.

12.4 If more than 12 % of the test specimen passes the No. 200 (75-μm) sieve, the soil shall be considered a

coarse-grained soil with fines. The fines are determined to be either clayey or silty based on the plasticity index versus liquid limit plot on Fig. 3. (See 9.8.2.1 if insufficient material available for testing). (See NOTE 6)

12.4.1 Classify the soil as a *clayey gravel*, GC, or *clayey sand*, SC, if the fines are clayey, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls on or above the "A" line and the plasticity index is greater than 7.

12.4.2 Classify the soil as a *silty gravel*, GM, or *silty sand*, SM, if the fines are silty, that is, the position of the plasticity index versus liquid limit plot, Fig. 3, falls below the "A" line or the plasticity index is less than 4.

12.4.3 If the fines plot as a silty clay, CL-ML, classify the soil as a *silty, clayey gravel*, GC-GM, if it is a gravel or a *silty, clayey sand*, SC-SM, if it is a sand.

12.5 If 5 to 12 % of the test specimen passes the No. 200 (75-μm) sieve, give the soil a dual classification using two group symbols.

12.5.1 The first group symbol shall correspond to that for a gravel or sand having less than 5 % fines (GW, GP, SW, SP), and the second symbol shall correspond to a gravel or sand having more than 12 % fines (GC, GM, SC, SM).

12.5.2 The group name shall correspond to the first group symbol plus "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example, well-graded gravel with clay, GW-GC; poorly graded sand with silt, SP-SM (See 9.8.2.1 if insufficient material available for testing).

NOTE 9—If the fines plot as a *silty clay*, CL-ML, the second group symbol should be either GC or SC. For example, a poorly graded sand with 10 % fines, a liquid limit of 20, and a plasticity index of 6 would be classified as a poorly graded sand with silty clay, SP-SC.

12.6 If the specimen is predominantly sand or gravel but contains 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example, poorly graded gravel with sand, clayey sand with gravel.

12.7 If the field sample contained any cobbles or boulders or both, the words "with cobbles," or "with cobbles and boulders" shall be added to the group name. For example, silty gravel with cobbles, GM.

### 13. Report

13.1 The report should include the group name, group symbol, and the results of the laboratory tests. The particle-size distribution shall be given in terms of percent of gravel, sand, and fines. The plot of the cumulative particle-size distribution curve shall be reported if used in classifying the soil. Report appropriate descriptive information according to

the procedures in Practice D 2488. A local or commercial name or geologic interpretation for the material may be added at the end of the descriptive information if identified as such. The test procedures used shall be referenced.

NOTE 10—*Example: Clayey Gravel with Sand and Cobbles (GC)*—46 % fine to coarse, hard, subrounded gravel; 30 % fine to coarse, hard, subrounded sand; 24 % clayey fines, LL = 38, PI = 19; weak reaction with HCl; original field sample had 4 % hard, subrounded cobbles; maximum dimension 150 mm.

In-Place Conditions—firm, homogeneous, dry, brown,  
Geologic Interpretation—alluvial fan.

NOTE 11—Other examples of soil descriptions are given in Appendix X1.

### 14. Keywords

14.1 Atterberg limits; classification; clay; gradation; gravel; laboratory classification; organic soils; sand; silt; soil classification; soil tests

## APPENDIXES

### (Nonmandatory Information)

#### X1. EXAMPLES OF DESCRIPTIONS USING SOIL CLASSIFICATION

X1.1 The following examples show how the information required in 13.1 can be reported. The appropriate descriptive information from Practice D 2488 is included for illustrative purposes. The additional descriptive terms that would accompany the soil classification should be based on the intended use of the classification and the individual circumstances.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—73 % fine to coarse, hard, subangular gravel; 23 % fine to coarse, hard, subangular sand; 4 % fines; Cc = 2.7, Cu = 12.4.

X1.1.2 *Silty Sand with Gravel (SM)*—61 % predominantly fine sand; 23 % silty fines, LL = 33, PI = 6; 16 % fine, hard, subrounded gravel; no reaction with HCl; (field sample smaller than recommended). *In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. thick, moist,

brown to gray; in-place density = 106 lb/ft<sup>3</sup> and in-place moisture = 9 %.

X1.1.3 *Organic Clay (OL)*—100 % fines, LL (not dried) = 32, LL (oven dried) = 21, PI (not dried) = 10; wet, dark brown, organic odor, weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—74 % fine to coarse, hard, subangular reddish sand; 26 % organic and silty dark-brown fines, LL (not dried) = 37, LL (oven dried) = 26, PI (not dried) = 6, wet, weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—78 % fine to coarse, hard, subrounded to subangular gravel; 16 % fine to coarse, hard, subrounded to subangular sand; 6 % silty (estimated) fines; moist, brown; no reaction with HCl; original field sample had 7 % hard, subrounded cobbles and 2 % hard, subrounded boulders with a maximum dimension of 18 in.

#### X2. USING SOIL CLASSIFICATION AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, ETC.

X2.1 The group names and symbols used in this standard may be used as a descriptive system applied to materials that exist in situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, etc.).

X2.2 Materials such as shells, crushed rock, slag, etc., should be identified as such. However, the procedures used in this standard for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, a classification in accordance with this standard may be assigned to aid in describing the material.

X2.3 If a classification is used, the group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how soil classifications could be incorporated into a description system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. pieces of shale from power auger hole, dry, brown, no reaction with HCl. After laboratory processing by slaking in water for 24 h, material classified as "Sandy Lean Clay (CL)"—61 % clayey fines, LL = 37, PI = 16; 33 % fine to medium sand; 6 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"—91 % fine to medium sand; 9 % silty (estimated) fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—62 % gravel-size broken shells;



31 % sand and sand-size shell pieces; 7 % fines; would be classified as "Poorly Graded Gravel with Sand (GP)".

X2.4.4 *Crushed Rock*—Processed gravel and cobbles from Pit No. 7; "Poorly Graded Gravel (GP)"—89 % fine,

hard, angular gravel-size particles; 11 % coarse, hard, angular sand-size particles, dry, tan; no reaction with HCl;  $C_c = 2.4$ ,  $C_u = 0.9$ .

### X3. PREPARATION AND TESTING FOR CLASSIFICATION PURPOSES BY THE WET METHOD

X3.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification using a wet-preparation procedure.

X3.2 Samples prepared in accordance with this procedure should contain as much of their natural water content as possible and every effort should be made during obtaining, preparing, and transporting the samples to maintain the natural moisture.

X3.3 The procedures to be followed in this standard assume that the field sample contains fines, sand, gravel, and plus 3-in. (75-mm) particles and the cumulative particle-size distribution plus the liquid limit and plasticity index values are required (see 9.8). Some of the following steps may be omitted when they are not applicable to the soil being tested.

X3.4 If the soil contains plus No. 200 (75- $\mu$ m) particles that would degrade during dry sieving, use a test procedure for determining the particle-size characteristics that prevents this degradation.

X3.5 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X3.6 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X3.6.1 Separate the field sample into two fractions on a 3-in. (75-mm) sieve, being careful to maintain the natural water content in the minus 3-in. (75-mm) fraction. Any particles adhering to the plus 3-in. (75-mm) particles shall be brushed or wiped off and placed in the fraction passing the 3-in. (75-mm) sieve.

X3.6.2 Determine the air-dry or oven-dry weight of the fraction retained on the 3-in. (75-mm) sieve. Determine the total (wet) weight of the fraction passing the 3-in. (75-mm) sieve.

X3.6.3 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve. Determine the water content, in accordance with Test Method D 2216, of a representative specimen with a minimum dry weight as required in 7.2. Save the water-content specimen for determination of the particle-size analysis in accordance with X3.8.

X3.6.4 Compute the dry weight of the fraction passing the 3-in. (75-mm) sieve based on the water content and total (wet) weight. Compute the total dry weight of the sample and calculate the percentage of material retained on the 3-in. (75-mm) sieve.

X3.7 Determine the liquid limit and plasticity index as follows:

X3.7.1 If the soil disaggregates readily, mix on a clean,

hard surface and select a representative sample by quartering in accordance with Practice C 702.

X3.7.1.1 If the soil contains coarse-grained particles coated with and bound together by tough clayey material, take extreme care in obtaining a representative portion of the No. 40 (425- $\mu$ m) fraction. Typically, a larger portion than normal has to be selected, such as the minimum weights required in 7.2.

X3.7.1.2 To obtain a representative specimen of a basically cohesive soil, it may be advantageous to pass the soil through a  $\frac{3}{4}$ -in. (19-mm) sieve or other convenient size so the material can be more easily mixed and then quartered or split to obtain the representative specimen.

X3.7.2 Process the representative specimen in accordance with Procedure B of Practice D 2217.

X3.7.3 Perform the liquid-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test.

X3.7.4 Perform the plastic-limit test in accordance with Test Method D 4318, except the soil shall not be air dried prior to the test, and calculate the plasticity index.

X3.8 Determine the particle-size distribution as follows:

X3.8.1 If the water content of the fraction passing the 3-in. (75-mm) sieve was required (X3.6.3), use the water-content specimen for determining the particle-size distribution. Otherwise, select a representative specimen in accordance with Practice C 702 with a minimum dry weight as required in 7.2.

X3.8.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of required sieves.

X3.8.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Method C 136. See 9.7 for the set of required sieves. The specimen should be soaked until all clayey aggregations have softened and then washed in accordance with Test Method C 117 prior to performing the particle-size distribution.

X3.8.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method C 117, being sure to soak the specimen long enough to soften all clayey aggregations, followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75- $\mu$ m) sieve.

X3.8.5 Calculate the percent fines, percent sand, and percent gravel in the minus 3-in. (75-mm) fraction for classification purposes.

#### X4. AIR-DRIED METHOD OF PREPARATION OF SOILS FOR TESTING FOR CLASSIFICATION PURPOSES

X4.1 This appendix describes the steps in preparing a soil sample for testing for purposes of soil classification when air-drying the soil before testing is specified or desired or when the natural moisture content is near that of an air-dried state.

X4.2 If the soil contains organic matter or mineral colloids that are irreversibly affected by air drying, the wet-preparation method as described in Appendix X3 should be used.

X4.3 Since this classification system is limited to the portion of a sample passing the 3-in. (75-mm) sieve, the plus 3-in. (75-mm) material shall be removed prior to the determination of the particle-size characteristics and the liquid limit and plasticity index.

X4.4 The portion of the field sample finer than the 3-in. (75-mm) sieve shall be obtained as follows:

X4.4.1 Air dry and weigh the field sample.

X4.4.2 Separate the field sample into two fractions on a 3-in. (75-mm) sieve.

X4.4.3 Weigh the two fractions and compute the percentage of the plus 3-in. (75-mm) material in the field sample.

X4.5 Determine the particle-size distribution and liquid limit and plasticity index as follows (see 9.8 for when these tests are required):

X4.5.1 Thoroughly mix the fraction passing the 3-in. (75-mm) sieve.

X4.5.2 If the cumulative particle-size distribution including a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 422. See 9.7 for the set of sieves that is required.

X4.5.3 If the cumulative particle-size distribution without a hydrometer analysis is required, determine the particle-size distribution in accordance with Test Method D 1140 followed by Method C 136. See 9.7 for the set of sieves that is required.

X4.5.4 If the cumulative particle-size distribution is not required, determine the percent fines, percent sand, and percent gravel in the specimen in accordance with Test Method D 1140 followed by Method C 136 using a nest of sieves which shall include a No. 4 (4.75-mm) sieve and a No. 200 (75-μm) sieve.

X4.5.5 If required, determine the liquid limit and the plasticity index of the test specimen in accordance with Test Method D 4318.

#### X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = cobbles
	b = boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-Sm, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

#### X6. RATIONALE

X6.1 Changes in this version from the previous D 2488 - 92 include the addition of X5 on Abbreviated Soil

Classification Symbols.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.



# Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>1</sup>

This standard is issued under the fixed designation D 2488; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.*

## 1. Scope

1.1 This practice covers procedures for the description of soils for engineering purposes.

1.2 This practice also describes a procedure for identifying soils, at the option of the user, based on the classification system described in Test Method D 2487. The identification is based on visual examination and manual tests. It must be clearly stated in reporting an identification that it is based on visual-manual procedures.

1.2.1 When precise classification of soils for engineering purposes is required, the procedures prescribed in Test Method D 2487 shall be used.

1.2.2 In this practice, the identification portion assigning a group symbol and name is limited to soil particles smaller than 3 in. (75 mm).

1.2.3 The identification portion of this practice is limited to naturally occurring soils (disturbed and undisturbed).

NOTE 1—This practice may be used as a descriptive system applied to such materials as shale, claystone, shells, crushed rock, etc. (See Appendix X2).

1.3 The descriptive information in this practice may be used with other soil classification systems or for materials other than naturally occurring soils.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific precautionary statements see Section 8.*

1.5 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>

D 1452 Practice for Soil Investigation and Sampling by Auger Borings<sup>2</sup>

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>

D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>

D 2113 Practice for Diamond Core Drilling for Site Investigation<sup>2</sup>

D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)<sup>2</sup>

D 4083 Practice for Description of Frozen Soils (Visual-Manual Procedure)<sup>2</sup>

## 3. Terminology

### 3.1 Definitions:

3.1.1 Except as listed below, all definitions are in accordance with Terminology D 653.

NOTE 2—For particles retained on a 3-in. (75-mm) US standard sieve, the following definitions are suggested:

*Cobbles*—particles of rock that will pass a 12-in. (300-mm) square opening and be retained on a 3-in. (75-mm) sieve, and

*Boulders*—particles of rock that will not pass a 12-in. (300-mm) square opening.

3.1.1.2 *clay*—soil passing a No. 200 (75- $\mu$ m) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents, and that exhibits considerable strength when air-dry. For classification, a clay is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index equal to or greater than 4, and the plot of plasticity index versus liquid limit falls on or above the "A" line (see Fig. 3 of Test Method D 2487).

3.1.1.3 *gravel*—particles of rock that will pass a 3-in. (75-mm) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions:

*coarse*—passes a 3-in. (75-mm) sieve and is retained on a 3/4-in. (19-mm) sieve.

*fine*—passes a 3/4-in. (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

3.1.1.4 *organic clay*—a clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.5 *organic silt*—a silt with sufficient organic content to influence the soil properties. For classification, an organic silt is a soil that would be classified as a silt except that its liquid limit value after oven drying is less than 75 % of its liquid limit value before oven drying.

3.1.1.6 *peat*—a soil composed primarily of vegetable tissue in various stages of decomposition usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

3.1.1.7 *sand*—particles of rock that will pass a No. 4

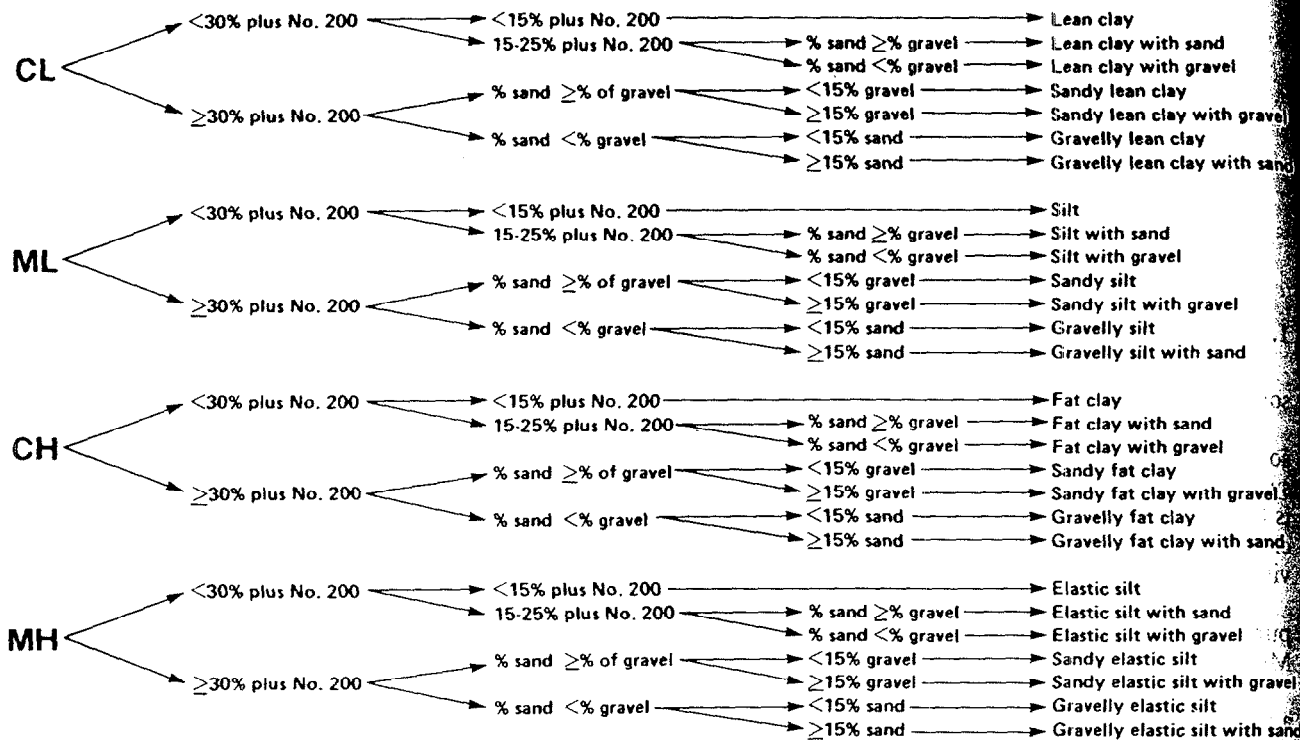
<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.07 on Identification and Classification of Soils.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 04.08.

GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1a Flow Chart for Identifying Inorganic Fine-Grained Soil (50 % or more fines)

(4.75-mm) sieve and be retained on a No. 200 (75-μm) sieve with the following subdivisions:

*coarse*—passes a No. 4 (4.75-mm) sieve and is retained on a No. 10 (2.00-mm) sieve.

*medium*—passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-μm) sieve.

*fine*—passes a No. 40 (425-μm) sieve and is retained on a No. 200 (75-μm) sieve.

3.1.1.8 *silt*—soil passing a No. 200 (75-μm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. For classification, a silt is a fine-grained soil, or the fine-grained portion of a soil, with a plasticity index less than 4, or the plot of plasticity index versus liquid limit falls below the “A” line (see Fig. 3 of Test Method D 2487).

4. Summary of Practice

4.1 Using visual examination and simple manual tests, this practice gives standardized criteria and procedures for describing and identifying soils.

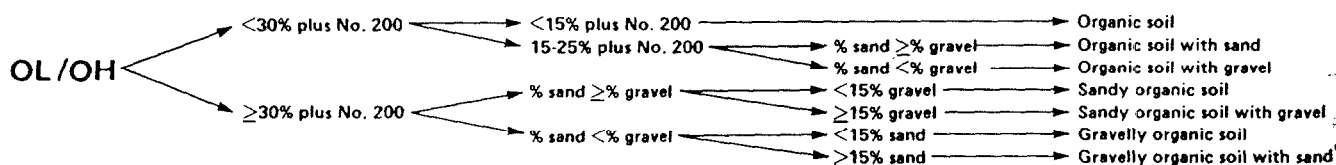
4.2 The soil can be given an identification by assigning a group symbol(s) and name. The flow charts, Figs. 1a and 1b for fine-grained soils, and Fig. 2, for coarse-grained soils, can be used to assign the appropriate group symbol(s) and name. If the soil has properties which do not distinctly place it into a specific group, borderline symbols may be used, see Appendix X3.

NOTE 3—It is suggested that a distinction be made between *dual symbols* and *borderline symbols*.

*Dual Symbol*—A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC, CL-ML used to indicate that the soil has been identified as having the properties of a classification in accordance with Test Method D 2487 where two symbols are required. Two symbols are required when the soil has between 5 and 12 % fines or

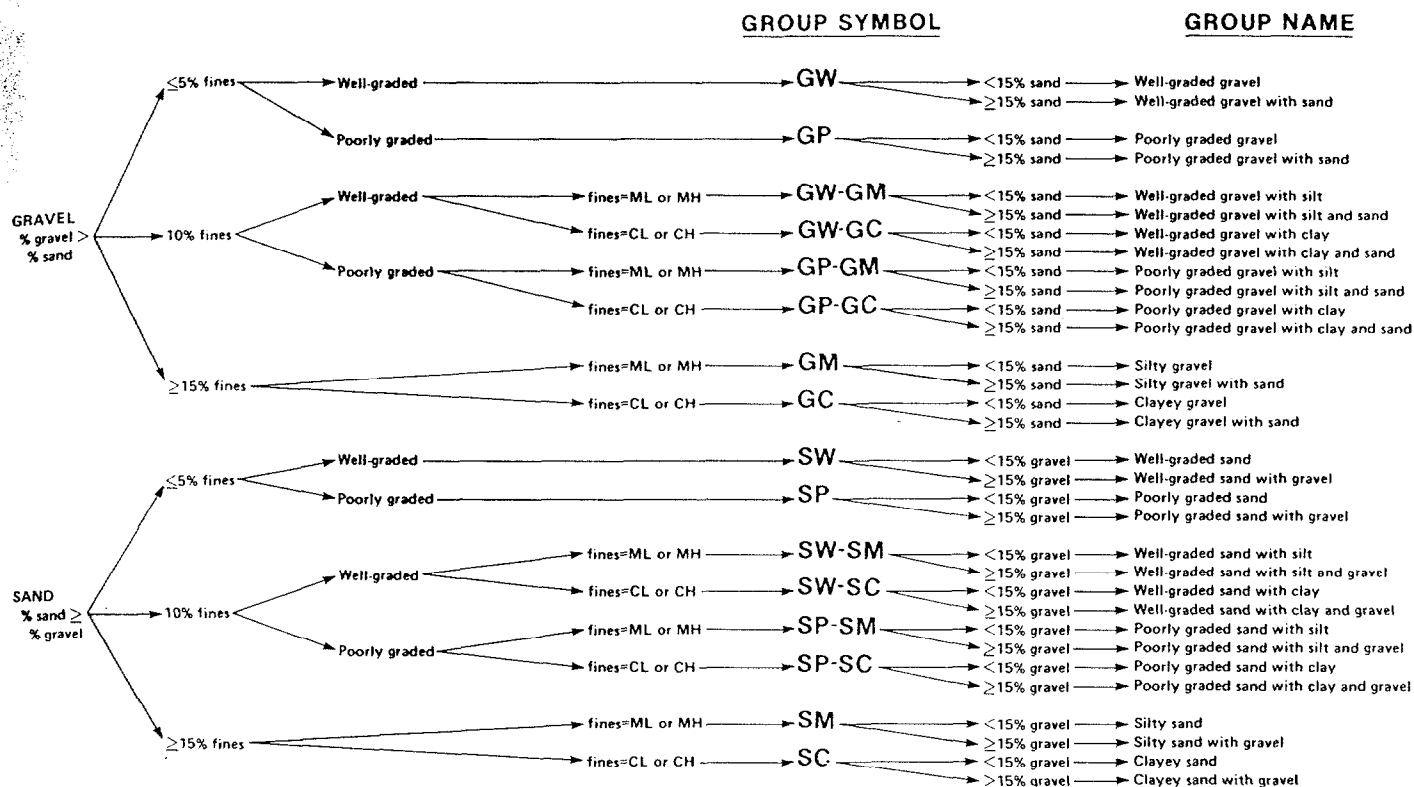
GROUP SYMBOL

GROUP NAME



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

FIG. 1b Flow Chart for Identifying Organic Fine-Grained Soil (50 % or more fines)



NOTE—Percentages are based on estimating amounts of fines, sand, and gravel to the nearest 5 %.

**FIG. 2 Flow Chart for Identifying Coarse-Grained Soils (less than 50 % fines)**

when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart.

**Borderline Symbol**—A borderline symbol is two symbols separated by a slash, for example, CL/CH, GM/SM, CL/ML. A borderline symbol should be used to indicate that the soil has been identified as having properties that do not distinctly place the soil into a specific group (see Appendix X3).

## 5. Significance and Use

5.1 The descriptive information required in this practice can be used to describe a soil to aid in the evaluation of its significant properties for engineering use.

5.2 The descriptive information required in this practice should be used to supplement the classification of a soil as determined by Test Method D 2487.

5.3 This practice may be used in identifying soils using the classification group symbols and names as prescribed in Test Method D 2487. Since the names and symbols used in this practice to identify the soils are the same as those used in Test Method D 2487, it shall be clearly stated in reports and all other appropriate documents, that the classification symbol and name are based on visual-manual procedures.

5.4 This practice is to be used not only for identification of soils in the field, but also in the office, laboratory, or wherever soil samples are inspected and described.

5.5 This practice has particular value in grouping similar soil samples so that only a minimum number of laboratory tests need be run for positive soil classification.

NOTE 4—The ability to describe and identify soils correctly is learned more readily under the guidance of experienced personnel, but it may also be acquired systematically by comparing numerical laboratory test

results for typical soils of each type with their visual and manual characteristics.

5.6 When describing and identifying soil samples from a given boring, test pit, or group of borings or pits, it is not necessary to follow all of the procedures in this practice for every sample. Soils which appear to be similar can be grouped together; one sample completely described and identified with the others referred to as similar based on performing only a few of the descriptive and identification procedures described in this practice.

5.7 This practice may be used in combination with Practice D 4083 when working with frozen soils.

## 6. Apparatus

6.1 *Required Apparatus:*

6.1.1 *Pocket Knife or Small Spatula.*

6.2 *Useful Auxiliary Apparatus:*

6.2.1 *Small Test Tube and Stopper* (or jar with a lid).

6.2.2 *Small Hand Lens.*

## 7. Reagents

7.1 *Purity of Water*—Unless otherwise indicated, references to water shall be understood to mean water from a city water supply or natural source, including non-potable water.

7.2 *Hydrochloric Acid*—A small bottle of dilute hydrochloric acid, HCl, one part HCl (10 N) to three parts water (This reagent is optional for use with this practice). See Section 8.

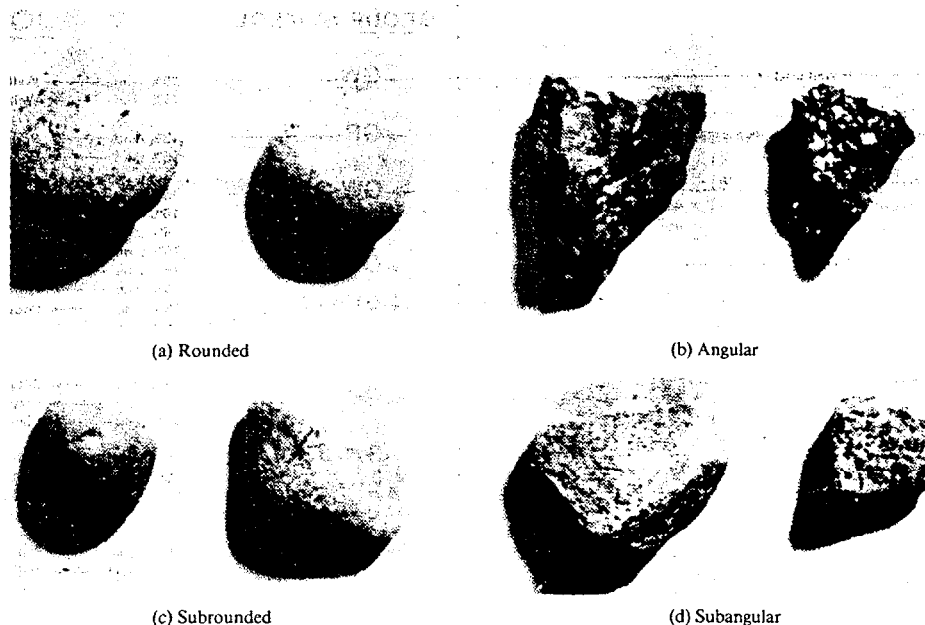


FIG. 3 Typical Angularity of Bulky Grains

## 8. Safety Precautions

8.1 When preparing the dilute HCl solution of one part concentrated hydrochloric acid (10 *N*) to three parts of distilled water, slowly add acid into water following necessary safety precautions. Handle with caution and store safely. If solution comes into contact with the skin, rinse thoroughly with water.

8.2 **Caution**—Do not add water to acid.

## 9. Sampling

9.1 The sample shall be considered to be representative of the stratum from which it was obtained by an appropriate, accepted, or standard procedure.

NOTE 5—Preferably, the sampling procedure should be identified as having been conducted in accordance with Practices D 1452, D 1587, or D 2113, or Method D 1586.

9.2 The sample shall be carefully identified as to origin.

NOTE 6—Remarks as to the origin may take the form of a boring number and sample number in conjunction with a job number, a geologic stratum, a pedologic horizon or a location description with respect to a permanent monument, a grid system or a station number and offset with respect to a stated centerline and a depth or elevation.

9.3 For accurate description and identification, the minimum amount of the specimen to be examined shall be in

TABLE 1 Criteria for Describing Angularity of Coarse-Grained Particles (see Fig. 3)

Description	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

accordance with the following schedule:

Maximum Particle Size, Sieve Opening	Minimum Specimen Size, Dry Weight
4.75 mm (No. 4)	100 g (0.25 lb)
9.5 mm (3/8 in.)	200 g (0.5 lb)
19.0 mm (3/4 in.)	1.0 kg (2.2 lb)
38.1 mm (1 1/2 in.)	8.0 kg (18 lb)
75.0 mm (3 in.)	60.0 kg (132 lb)

NOTE 7—If random isolated particles are encountered that are significantly larger than the particles in the soil matrix, the soil matrix can be accurately described and identified in accordance with the preceding schedule.

9.4 If the field sample or specimen being examined is smaller than the minimum recommended amount, the report shall include an appropriate remark.

## 10. Descriptive Information for Soils

10.1 **Angularity**—Describe the angularity of the sand (coarse sizes only), gravel, cobbles, and boulders, as angular, subangular, subrounded, or rounded in accordance with the criteria in Table 1 and Fig. 3. A range of angularity may be stated, such as: subrounded to rounded.

10.2 **Shape**—Describe the shape of the gravel, cobbles, and boulders as flat, elongated, or flat and elongated if they meet the criteria in Table 2 and Fig. 4. Otherwise, do not mention the shape. Indicate the fraction of the particles that have the shape, such as: one-third of the gravel particles are flat.

10.3 **Color**—Describe the color. Color is an important property in identifying organic soils, and within a given

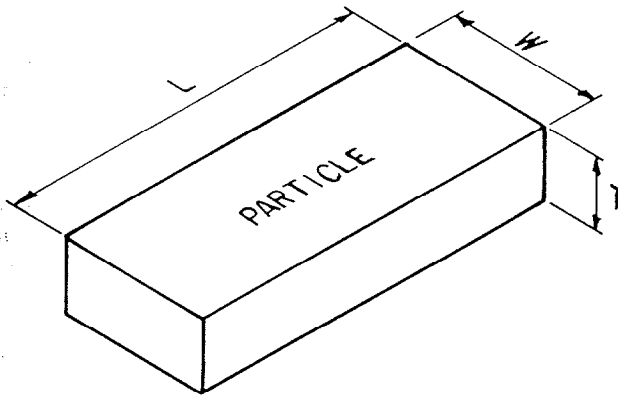
TABLE 2 Criteria for Describing Particle Shape (see Fig. 4)

The particle shape shall be described as follows where length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle, respectively.

Flat	Particles with width/thickness > 3
Elongated	Particles with length/width > 3
Flat and elongated	Particles meet criteria for both flat and elongated

## PARTICLE SHAPE

W = WIDTH  
T = THICKNESS  
L = LENGTH



FLAT:  $W/T > 3$   
ELONGATED:  $L/W > 3$   
FLAT AND ELONGATED:  
- meets both criteria

FIG. 4 Criteria for Particle Shape

TABLE 3 Criteria for Describing Moisture Condition

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

locality it may also be useful in identifying materials of similar geologic origin. If the sample contains layers or patches of varying colors, this shall be noted and all representative colors shall be described. The color shall be described for moist samples. If the color represents a dry condition, this shall be stated in the report.

10.4 *Odor*—Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples, but if the samples are dried, the odor may often be revived by heating a moistened sample. If the odor is unusual (petroleum product, chemical, and the like), it shall be described.

10.5 *Moisture Condition*—Describe the moisture condition as dry, moist, or wet, in accordance with the criteria in Table 3.

10.6 *HCl Reaction*—Describe the reaction with HCl as none, weak, or strong, in accordance with the criteria in Table 4. Since calcium carbonate is a common cementing agent, a report of its presence on the basis of the reaction with dilute hydrochloric acid is important.

TABLE 4 Criteria for Describing the Reaction With HCl

Description	Criteria
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

TABLE 5 Criteria for Describing Consistency

Description	Criteria
Very soft	Thumb will penetrate soil more than 1 in. (25 mm)
Soft	Thumb will penetrate soil about 1 in. (25 mm)
Firm	Thumb will indent soil about 1/4 in. (6 mm)
Hard	Thumb will not indent soil but readily indented with thumbnail
Very hard	Thumbnail will not indent soil

10.7 *Consistency*—For intact fine-grained soil, describe the consistency as very soft, soft, firm, hard, or very hard, in accordance with the criteria in Table 5. This observation is inappropriate for soils with significant amounts of gravel.

10.8 *Cementation*—Describe the cementation of intact coarse-grained soils as weak, moderate, or strong, in accordance with the criteria in Table 6.

10.9 *Structure*—Describe the structure of intact soils in accordance with the criteria in Table 7.

10.10 *Range of Particle Sizes*—For gravel and sand components, describe the range of particle sizes within each component as defined in 3.1.2 and 3.1.6. For example, about 20 % fine to coarse gravel, about 40 % fine to coarse sand.

10.11 *Maximum Particle Size*—Describe the maximum particle size found in the sample in accordance with the following information:

10.11.1 *Sand Size*—If the maximum particle size is a sand size, describe as fine, medium, or coarse as defined in 3.1.6. For example: maximum particle size, medium sand.

10.11.2 *Gravel Size*—If the maximum particle size is a gravel size, describe the maximum particle size as the smallest sieve opening that the particle will pass. For example, maximum particle size, 1 1/2 in. (will pass a 1 1/2-in. square opening but not a 3/4-in. square opening).

10.11.3 *Cobble or Boulder Size*—If the maximum particle size is a cobble or boulder size, describe the maximum dimension of the largest particle. For example: maximum dimension, 18 in. (450 mm).

10.12 *Hardness*—Describe the hardness of coarse sand and larger particles as hard, or state what happens when the particles are hit by a hammer, for example, gravel-size particles fracture with considerable hammer blow, some gravel-size particles crumble with hammer blow. "Hard" means particles do not crack, fracture, or crumble under a hammer blow.

10.13 Additional comments shall be noted, such as the presence of roots or root holes, difficulty in drilling or augering hole, caving of trench or hole, or the presence of mica.

10.14 A local or commercial name or a geologic interpretation

TABLE 6 Criteria for Describing Cementation

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure



TABLE 7 Criteria for Describing Structure

Description	Criteria
Stratified	Alternating layers of varying material or color with layers at least 6 mm thick; note thickness
Laminated	Alternating layers of varying material or color with the layers less than 6 mm thick; note thickness
Fissured	Breaks along definite planes of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness
Homogeneous	Same color and appearance throughout

tation of the soil, or both, may be added if identified as such.

10.15 A classification or identification of the soil in accordance with other classification systems may be added if identified as such.

### 11. Identification of Peat

11.1 A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor, shall be designated as a highly organic soil and shall be identified as peat, PT, and not subjected to the identification procedures described hereafter.

### 12. Preparation for Identification

12.1 The soil identification portion of this practice is based on the portion of the soil sample that will pass a 3-in. (75-mm) sieve. The larger than 3-in. (75-mm) particles must be removed, manually, for a loose sample, or mentally, for an intact sample before classifying the soil.

12.2 Estimate and note the percentage of cobbles and the percentage of boulders. Performed visually, these estimates will be on the basis of volume percentage.

NOTE 8—Since the percentages of the particle-size distribution in Test Method D 2487 are by dry weight, and the estimates of percentages for gravel, sand, and fines in this practice are by dry weight, it is recommended that the report state that the percentages of cobbles and boulders are by volume.

12.3 Of the fraction of the soil smaller than 3 in. (75 mm), estimate and note the percentage, by dry weight, of the gravel, sand, and fines (see Appendix X4 for suggested procedures).

NOTE 9—Since the particle-size components appear visually on the basis of volume, considerable experience is required to estimate the percentages on the basis of dry weight. Frequent comparisons with laboratory particle-size analyses should be made.

12.3.1 The percentages shall be estimated to the closest 5 %. The percentages of gravel, sand, and fines must add up to 100 %.

12.3.2 If one of the components is present but not in sufficient quantity to be considered 5 % of the smaller than 3-in. (75-mm) portion, indicate its presence by the term *trace*, for example, trace of fines. A trace is not to be considered in the total of 100 % for the components.

### 13. Preliminary Identification

13.1 The soil is *fine grained* if it contains 50 % or more

fines. Follow the procedures for identifying fine-grained soils of Section 14.

13.2 The soil is *coarse grained* if it contains less than 50 % fines. Follow the procedures for identifying coarse-grained soils of Section 15.

### 14. Procedure for Identifying Fine-Grained Soils

14.1 Select a representative sample of the material for examination. Remove particles larger than the No. 40 sieve (medium sand and larger) until a specimen equivalent to about a handful of material is available. Use this specimen for performing the dry strength, dilatancy, and toughness tests.

#### 14.2 Dry Strength:

14.2.1 From the specimen, select enough material to mold into a ball about 1 in. (25 mm) in diameter. Mold the material until it has the consistency of putty, adding water if necessary.

14.2.2 From the molded material, make at least three test specimens. A test specimen shall be a ball of material about 1/2 in. (12 mm) in diameter. Allow the test specimens to dry in air, or sun, or by artificial means, as long as the temperature does not exceed 60°C.

14.2.3 If the test specimen contains natural dry lumps, those that are about 1/2 in. (12 mm) in diameter may be used in place of the molded balls.

NOTE 10—The process of molding and drying usually produces higher strengths than are found in natural dry lumps of soil.

14.2.4 Test the strength of the dry balls or lumps by crushing between the fingers. Note the strength as none, low, medium, high, or very high in accordance with the criteria in Table 8. If natural dry lumps are used, do not use the results of any of the lumps that are found to contain particles of coarse sand.

14.2.5 The presence of high-strength water-soluble cementing materials, such as calcium carbonate, may cause exceptionally high dry strengths. The presence of calcium carbonate can usually be detected from the intensity of the reaction with dilute hydrochloric acid (see 10.6).

#### 14.3 Dilatancy:

14.3.1 From the specimen, select enough material to mold into a ball about 1/2 in. (12 mm) in diameter. Mold the material, adding water if necessary, until it has a soft, but not sticky, consistency.

14.3.2 Smooth the soil ball in the palm of one hand with the blade of a knife or small spatula. Shake horizontally, striking the side of the hand vigorously against the other hand several times. Note the reaction of water appearing on

TABLE 8 Criteria for Describing Dry Strength

Description	Criteria
None	The dry specimen crumbles into powder with mere pressure of handling
Low	The dry specimen crumbles into powder with some finger pressure
Medium	The dry specimen breaks into pieces or crumbles with considerable finger pressure
High	The dry specimen cannot be broken with finger pressure. Specimen will break into pieces between thumb and a hard surface
Very high	The dry specimen cannot be broken between the thumb and a hard surface

15.2 The soil is a *sand* if the percentage of gravel is estimated to be equal to or less than the percentage of sand.

15.3 The soil is a *clean gravel* or *clean sand* if the percentage of fines is estimated to be 5 % or less.

15.3.1 Identify the soil as a *well-graded gravel*, GW, or as a *well-graded sand*, SW, if it has a wide range of particle sizes and substantial amounts of the intermediate particle sizes.

15.3.2 Identify the soil as a *poorly graded gravel*, GP, or as a *poorly graded sand*, SP, if it consists predominantly of one size (uniformly graded), or it has a wide range of sizes with some intermediate sizes obviously missing (gap or skip graded).

15.4 The soil is either a *gravel with fines* or a *sand with fines* if the percentage of fines is estimated to be 15 % or more.

15.4.1 Identify the soil as a *clayey gravel*, GC, or a *clayey sand*, SC, if the fines are clayey as determined by the procedures in Section 14.

15.4.2 Identify the soil as a *silty gravel*, GM, or a *silty sand*, SM, if the fines are silty as determined by the procedures in Section 14.

15.5 If the soil is estimated to contain 10 % fines, give the soil a dual identification using two group symbols.

15.5.1 The first group symbol shall correspond to a clean gravel or sand (GW, GP, SW, SP) and the second symbol shall correspond to a gravel or sand with fines (GC, GM, SC, SM).

15.5.2 The group name shall correspond to the first group symbol plus the words "with clay" or "with silt" to indicate the plasticity characteristics of the fines. For example: "well-graded gravel with clay, GW-GC" or "poorly graded sand with silt, SP-SM" (see Fig. 2).

15.6 If the specimen is predominantly sand or gravel but contains an estimated 15 % or more of the other coarse-grained constituent, the words "with gravel" or "with sand" shall be added to the group name. For example: "poorly graded gravel with sand, GP" or "clayey sand with gravel, SC" (see Fig. 2).

15.7 If the field sample contains any cobbles or boulders, or both, the words "with cobbles" or "with cobbles and boulders" shall be added to the group name. For example: "silty gravel with cobbles, GM."

## 16. Report

16.1 The report shall include the information as to origin, and the items indicated in Table 13.

NOTE 13—Example: *Clayey Gravel with Sand and Cobbles, GC*—About 50 % fine to coarse, subrounded to subangular gravel; about 30 % fine to coarse, subrounded sand; about 20 % fines with medium plasticity, high dry strength, no dilatancy, medium toughness; weak

TABLE 13 Checklist for Description of Soils

1. Group name
2. Group symbol
3. Percent of cobbles or boulders, or both (by volume)
4. Percent of gravel, sand, or fines, or all three (by dry weight)
5. Particle-size range:
  - Gravel—fine, coarse
  - Sand—fine, medium, coarse
6. Particle angularity: angular, subangular, subrounded, rounded
7. Particle shape: (if appropriate) flat, elongated, flat and elongated
8. Maximum particle size or dimension
9. Hardness of coarse sand and larger particles
10. Plasticity of fines: nonplastic, low, medium, high
11. Dry strength: none, low, medium, high, very high
12. Dilatancy: none, slow, rapid
13. Toughness: low, medium, high
14. Color (in moist condition)
15. Odor (mention only if organic or unusual)
16. Moisture: dry, moist, wet
17. Reaction with HCl: none, weak, strong
- For intact samples:
  - 18. Consistency (fine-grained soils only): very soft, soft, firm, hard, very hard
  - 19. Structure: stratified, laminated, fissured, slickensided, lensed, homogeneous
  - 20. Cementation: weak, moderate, strong
  - 21. Local name
  - 22. Geologic interpretation
  - 23. Additional comments: presence of roots or root holes, presence of mica, gypsum, etc., surface coatings on coarse-grained particles, caving or sloughing of auger hole or trench sides, difficulty in augering or excavating, etc.

reaction with HCl; original field sample had about 5 % (by volume) subrounded cobbles, maximum dimension, 150 mm.

In-Place Conditions—Firm, homogeneous, dry, brown

Geologic Interpretation—Alluvial fan

NOTE 14—Other examples of soil descriptions and identification are given in Appendixes X1 and X2.

NOTE 15—If desired, the percentages of gravel, sand, and fines may be stated in terms indicating a range of percentages, as follows:

Trace—Particles are present but estimated to be less than 5 %

Few—5 to 10 %

Little—15 to 25 %

Some—30 to 45 %

Mostly—50 to 100 %

16.2 If, in the soil description, the soil is identified using a classification group symbol and name as described in Test Method D 2487, it must be distinctly and clearly stated in log forms, summary tables, reports, and the like, that the symbol and name are based on visual-manual procedures.

## 17. Precision and Bias

17.1 This practice provides qualitative information only, therefore, a precision and bias statement is not applicable.

## 18. Keywords

18.1 classification; clay; gravel; organic soils; sand; silt; soil classification; soil description; visual classification

## APPENDIXES

### (Nonmandatory Information)

#### X1. EXAMPLES OF VISUAL SOIL DESCRIPTIONS

X1.1 The following examples show how the information required in 16.1 can be reported. The information that is included in descriptions should be based on individual circumstances and need.

X1.1.1 *Well-Graded Gravel with Sand (GW)*—About 75 % fine to coarse, hard, subangular gravel; about 25 % fine to coarse, hard, subangular sand; trace of fines; maximum size, 75 mm, brown, dry; no reaction with HCl.

X1.1.2 *Silty Sand with Gravel (SM)*—About 60 % predominantly fine sand; about 25 % silty fines with low plasticity, low dry strength, rapid dilatancy, and low toughness; about 15 % fine, hard, subrounded gravel, a few gravel-size particles fractured with hammer blow; maximum size, 25 mm; no reaction with HCl (Note—Field sample size smaller than recommended).

*In-Place Conditions*—Firm, stratified and contains lenses of silt 1 to 2 in. (25 to 50 mm) thick, moist, brown to gray;

in-place density 106 lb/ft<sup>3</sup>; in-place moisture 9 %.

X1.1.3 *Organic Soil (OL/OH)*—About 100 % fines with low plasticity, slow dilatancy, low dry strength, and low toughness; wet, dark brown, organic odor; weak reaction with HCl.

X1.1.4 *Silty Sand with Organic Fines (SM)*—About 75 % fine to coarse, hard, subangular reddish sand; about 25 % organic and silty dark brown nonplastic fines with no dry strength and slow dilatancy; wet; maximum size, coarse sand; weak reaction with HCl.

X1.1.5 *Poorly Graded Gravel with Silt, Sand, Cobbles and Boulders (GP-GM)*—About 75 % fine to coarse, hard, subrounded to subangular gravel; about 15 % fine, hard, subrounded to subangular sand; about 10 % silty nonplastic fines; moist, brown; no reaction with HCl; original field sample had about 5 % (by volume) hard, subrounded cobbles and a trace of hard, subrounded boulders, with a maximum dimension of 18 in. (450 mm).

#### X2. USING THE IDENTIFICATION PROCEDURE AS A DESCRIPTIVE SYSTEM FOR SHALE, CLAYSTONE, SHELLS, SLAG, CRUSHED ROCK, AND THE LIKE

X2.1 The identification procedure may be used as a descriptive system applied to materials that exist in-situ as shale, claystone, sandstone, siltstone, mudstone, etc., but convert to soils after field or laboratory processing (crushing, slaking, and the like).

X2.2 Materials such as shells, crushed rock, slag, and the like, should be identified as such. However, the procedures used in this practice for describing the particle size and plasticity characteristics may be used in the description of the material. If desired, an identification using a group name and symbol according to this practice may be assigned to aid in describing the material.

X2.3 The group symbol(s) and group names should be placed in quotation marks or noted with some type of distinguishing symbol. See examples.

X2.4 Examples of how group names and symbols can be incorporated into a descriptive system for materials that are not naturally occurring soils are as follows:

X2.4.1 *Shale Chunks*—Retrieved as 2 to 4-in. (50 to

100-mm) pieces of shale from power auger hole, dry, brown, no reaction with HCl. After slaking in water for 24 h, material identified as "Sandy Lean Clay (CL)"; about 60 % fines with medium plasticity, high dry strength, no dilatancy, and medium toughness; about 35 % fine to medium, hard sand; about 5 % gravel-size pieces of shale.

X2.4.2 *Crushed Sandstone*—Product of commercial crushing operation; "Poorly Graded Sand with Silt (SP-SM)"; about 90 % fine to medium sand; about 10 % nonplastic fines; dry, reddish-brown, strong reaction with HCl.

X2.4.3 *Broken Shells*—About 60 % gravel-size broken shells; about 30 % sand and sand-size shell pieces; about 10 % fines; "Poorly Graded Gravel with Sand (GP)."

X2.4.4 *Crushed Rock*—Processed from gravel and cobbles in Pit No. 7; "Poorly Graded Gravel (GP)"; about 90 % fine, hard, angular gravel-size particles; about 10 % coarse, hard, angular sand-size particles; dry, tan; no reaction with HCl.

#### X3. SUGGESTED PROCEDURE FOR USING A BORDERLINE SYMBOL FOR SOILS WITH TWO POSSIBLE IDENTIFICATIONS.

X3.1 Since this practice is based on estimates of particle size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two

possible basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example: SC/CL or CL/CH.

X3.1.1 A borderline symbol may be used when the

percentage of fines is estimated to be between 45 and 55 %. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil. For example: GM/ML or CL/SC.

X3.1.2 A borderline symbol may be used when the percentage of sand and the percentage of gravel are estimated to be about the same. For example: GP/SP, SC/GC, GM/SM. It is practically impossible to have a soil that would have a borderline symbol of GW/SW.

X3.1.3 A borderline symbol may be used when the soil could be either well graded or poorly graded. For example: GW/GP, SW/SP.

X3.1.4 A borderline symbol may be used when the soil could either be a silt or a clay. For example: CL/ML, CH/MH, SC/SM.

X3.1.5 A borderline symbol may be used when a fine-

grained soil has properties that indicate that it is at the boundary between a soil of low compressibility and a soil of high compressibility. For example: CL/CH, MH/ML.

X3.2 The order of the borderline symbols should reflect similarity to surrounding or adjacent soils. For example: soils in a borrow area have been identified as CH. One sample is considered to have a borderline symbol of CL and CH. To show similarity, the borderline symbol should be CH/CL.

X3.3 The group name for a soil with a borderline symbol should be the group name for the first symbol, except for:

CL/CH lean to fat clay

ML/CL clayey silt

CL/ML silty clay

X3.4 The use of a borderline symbol should not be used indiscriminately. Every effort shall be made to first place the soil into a single group.

#### X4. SUGGESTED PROCEDURES FOR ESTIMATING THE PERCENTAGES OF GRAVEL, SAND, AND FINES IN A SOIL SAMPLE

X4.1 *Jar Method*—The relative percentage of coarse- and fine-grained material may be estimated by thoroughly shaking a mixture of soil and water in a test tube or jar, and then allowing the mixture to settle. The coarse particles will fall to the bottom and successively finer particles will be deposited with increasing time; the sand sizes will fall out of suspension in 20 to 30 s. The relative proportions can be estimated from the relative volume of each size separate. This method should be correlated to particle-size laboratory determinations.

X4.2 *Visual Method*—Mentally visualize the gravel size particles placed in a sack (or other container) or sacks. Then, do the same with the sand size particles and the fines. Then, mentally compare the number of sacks to estimate the percentage of plus No. 4 sieve size and minus No. 4 sieve size

present. The percentages of sand and fines in the minus sieve size No. 4 material can then be estimated from the wash test (X4.3).

X4.3 *Wash Test (for relative percentages of sand and fines)*—Select and moisten enough minus No. 4 sieve size material to form a 1-in (25-mm) cube of soil. Cut the cube in half, set one-half to the side, and place the other half in a small dish. Wash and decant the fines out of the material in the dish until the wash water is clear and then compare the two samples and estimate the percentage of sand and fines. Remember that the percentage is based on weight, not volume. However, the volume comparison will provide a reasonable indication of grain size percentages.

X4.3.1 While washing, it may be necessary to break down lumps of fines with the finger to get the correct percentages.

#### X5. ABBREVIATED SOIL CLASSIFICATION SYMBOLS

X5.1 In some cases, because of lack of space, an abbreviated system may be useful to indicate the soil classification symbol and name. Examples of such cases would be graphical logs, databases, tables, etc.

X5.2 This abbreviated system is not a substitute for the full name and descriptive information but can be used in supplementary presentations when the complete description is referenced.

X5.3 The abbreviated system should consist of the soil classification symbol based on this standard with appropriate lower case letter prefixes and suffixes as:

Prefix:	Suffix:
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

X5.4 The soil classification symbol is to be enclosed in parenthesis. Some examples would be:

Group Symbol and Full Name	Abbreviated
CL, Sandy lean clay	s(CL)
SP-SM, Poorly graded sand with silt and gravel	(SP-SM)g
GP, poorly graded gravel with sand, cobbles, and boulders	(GP)scb
ML, gravelly silt with sand and cobbles	g(ML)sc

## X6. RATIONALE

Changes in this version from the previous version, Classification Symbols.  
D 2488 - 90, include the addition of X5 on Abbreviated Soil

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**ATTACHMENT C**  
**SOIL AND ROCK DESCRIPTION SUMMARY**

SOIL DESCRIPTION			ROCK DESCRIPTIONS		
GRAIN SIZE IDENTIFICATION			HARDNESS		
NAME	SIZE LIMITS		Very Soft -	Easily gouged by knife, easily scratched by fingernail, easily broken by hand	
Boulder	12" OR MORE		Soft -	Gouged by knife, scratched by fingernail, difficult to break by hand, powders with hammer	
Cobbles	3" - 12"		Medium Hard -	Easily scratched by knife, easily broken with hammer	
Coarse Gravel	3/4" - 3"		Hard -	Difficult to scratch, breaks with hammer	
Fine Gravel	4.76 mm (#4) - 3/4"		Very Hard -	Difficult to break, rings when struck	
Coarse Sand	2 mm (#10) - 4.76 mm (#4)				
Medium Sand	0.42 mm (#40) - 2 mm (#10)				
Fine Sand	0.074 mm (#200)-0.42 mm (#40)				
Silt	0.002 mm-0.074 mm (#200)				
Clay	Less than 0.002 mm				
RELATIVE DENSITY			WEATHERING		
NONCOHESIVE SOIL			Decomposed	Soft to Very soft, bedding and fractures indistinct, no cementation.	
TERM	SPT (Blows/ft)		Highly Weathered	Very soft to soft, with medium hard relict rock fragments; little to moderate cementation. Vugs, openings in bedding and fractures (may be filled).	
Very Loose	Below 4		Weathered	Soft to medium hard. Good cementation. bedding and fractures are pronounced. Uniformly stained.	
Loose	4-10		Slightly Weathered	Medium hard. Fractures pronounced, non-uniform staining, bedding distinct.	
Medium Dense	10-30		Fresh	Medium hard to hard. No staining. Fractures may be present. Bedding may or may not be indistinct.	
Dense	30-50		BEDDING AND FRACTURES:		
Very Dense	OVER 50		SPACING	BEDDING	FRACTURES
COHESIVE SOILS			LESS THAN 1/2" (1 cm)	Indistinct	
TERM	SPT (Blows/ft)		1/2" to 1" (1cm-3cm)	Laminated	Fissile
Very Soft	BELOW 2		1" TO 4" (3cm-10cm)	Very Thin	Very Close
Soft	2-4		4" TO 1' (10cm-30cm)	Thin	Close
Medium Stiff	4-8		1' TO 3' (30 cm-1m)	Moderate	Moderate
Stiff	8-15		3' TO 10' (1m-3m)	Thick	Wide
Very Stiff	15-30			Massive	Very Wide
Hard	OVER 30				
MOISTURE					
DESCRIPTIVE TERMS					
Dry	Trace	0-10%			
Damp	Little	10-20%			
Moist	Some	20-35%			
Wet	And	35-50%			
CONTACTS:			SAMPLE TYPE		
_____ = DEFINITE			HS = Hollow Stem		
_____ = INDEFINITE			NP = Non Plastic		
..... = GRADATIONAL			-PL = Below the Plastic Limit		
			PL = At the Plastic Limit		
			+ PL = Above the Plastic Limit		
			+ LL = Above the Liquid Limit		
			SPT = Standard Penetration Test		
			RQD = Rock Quality Designation		

# ROCK SYMBOLS

# HARDNESS

	CONGLOMERATE		LIMESTONE
	BRECCIA		DOLOMITE
	SANDSTONE		COAL
	SILTSTONE		VOID
	SHALE		UNDIFFERENTIATED
	CLAYSTONE		

V. SOFT - CORE RECOVERY < 50%, EASILY GOUGED BY KNIFE OR SCREWDRIVER, EASILY SCRATCHED BY FINGERNAIL, EASILY BROKEN BY HAND

SOFT - CORE RECOVERY 50 - 75%, GOUGED BY KNIFE OR SCREWDRIVER, SCRATCHED BY FINGERNAIL, DIFFICULT TO BREAK BY HAND, POWDERS w/HAMMER

MED. HD. - CORE RECOVERY > 75%, EASILY SCRATCHED BY KNIFE OR SCREWDRIVER, EASILY BROKEN BY HAMMER

HD. - DIFFICULT TO SCRATCH, BREAKS w/HAMMER

V. HD. - DIFFICULT TO BREAK, RINGS WHEN STRUCK

## SPACING

LESS THAN 1/8" (1cm)  
1/8" To 1" (1cm-3cm)  
1" To 4" (3cm-10cm)  
4" To 1' (10cm-30cm)  
1' To 3' (30cm-1m)  
3' To 10' (1m-3m)

## BEDDING

INDISTINCT  
LAMINATED  
VERY THIN  
THIN  
MODERATE  
THICK  
MASSIVE

## FRACTURES

FISSILE  
VERY CLOSE  
CLOSE  
MODERATE  
WIDE  
VERY WIDE

## WEATHERING

DECOMPOSED - SOFT - V. SOFT, BEDDING AND FRACTURES INDISTINCT, NO CEMENTATION

HL WTHR. - V. SOFT - SOFT, w/MED. HD. RELICT ROCK FRAGMENTS; LITTLE TO MOD. CEMENTATION, VUGS, OPENINGS IN BEDDING AND FRACTURES (MAY BE CLAY OR CALC. FILLED)

WTHR. - SOFT TO MED. HD., GOOD CEMENTATION, BEDDING AND FRACTURES ARE PRONOUNCED, UNIFORMLY STAINED

SL WTHR. - MED. HD., FRACTURES PRONOUNCED, NON-UNIFORM STAINING, BEDDING DISTINCT

FRESH - MED. HD. TO HD., NO STAINING, FRACTURES MAY BE PRESENT, BEDDING MAY OR MAY NOT BE DISTINCT

## COMMON LOCAL SEDIMENTARY ROCK CLASSIFICATIONS

MM APP. SIEVE SIZE		NO FIZZ		SLIGHT FIZZ % CARBONATE →		RAPID FIZZ		FRESH	
2.0 #10-20		CONGLOMERATE - If particles rounded BRECCIA - If particles angular; classify both particles and matrix as below							
VERY COARSE GRAINED		SANDSTONE	CALCAREOUS SANDSTONE	ARENACEOUS LIMESTONE	LIMESTONE	EASILY VISIBLE - ROUGH			
#20-36									
COARSE GRAINED									
.5 #40-60									
MEDIUM GRAINED									
.25 #60-100									
FINE GRAINED									
.125 #100-200									
VERY FINE GRAINED									
.005		SILTSTONE SHALE (IF LAM OR FIS.)	CALC. SILTSTONE CALC. SHALE (MARL)	SILTY LIMESTONE	CRYSTALLINE	SLIGHTLY VISIBLE GRITTY			
		CLAYSTONE	CALC. CLAYSTONE	(ARG) CLAYEY LIMESTONE		NOT VISIBLE SMOOTH			

$$ROD = \frac{L}{R} \quad \text{— N TYPE CORE ONLY}$$

L = TOTAL LENGTH IN A RUN OF CORE PIECES LONGER THAN 4"

R = LENGTH OF THE RUN

→ % SILICATE

## ROCK DESCRIPTIONS



**APPENDIX C**  
**FIELD SCREENING PROCEDURES FOR PCBS**

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# RAPID PREP™ FLOWCHART: PCB SOIL EXTRACTION PROTOCOL

1



Disregard Soil Extraction steps 1 – 3, refer to User's Guide included in Sample Extraction Kit

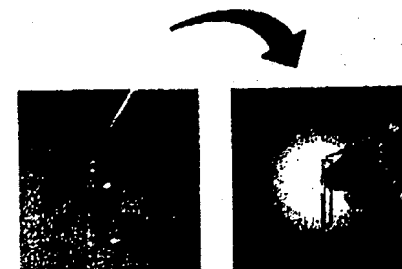
## 4a DILUTION SCHEME

For samples 500 ppb to 10 ppm:  
Add 25  $\mu$ L of filtered extract to a vial of PCB Extract Diluent (25 mL).  
Cap and mix by by Inverting several times.  
Factor = 2000.



## 4b DILUTION SCHEME

For samples 50 ppm to 1000 ppm:  
Add 25  $\mu$ L of filtered extract to a vial of PCB Extract Diluent (25 mL).  
Mix.  
Add 25  $\mu$ L of diluted extract (from 1st dilution) to 2.5 mL of PCB RaPID Assay Diluent.  
Mix thoroughly.  
Factor = 200,000.



## 5 ASSAY

Analyze diluted extract as "sample" according to the PCB RaPID Assay procedure (see reverse).

Multiply results of extracted soil samples by appropriate factor.

For Ordering or Technical Assistance Contact:



Strategic Diagnostics Inc.  
111 Pencader Drive  
Newark, DE 19702  
Phone: (800) 544-8881  
Fax: (302) 456-8782

gnostics, Inc.

PCB Rapid Assay Kits  
Part # A00133 30 Tests  
# A00134 100 Tests

RaPID Prep Soil Collection Kit A00127  
RaPID Prep PCB Sample Extraction Kit A00137

# PCB FLOWCHART: SOIL PROTOCOL

1

Remove upper rack from magnetic base.

Label test tubes for Standards, Control, and Samples.

Tube #	Content
1, 2	Diluent/Zero Standard, 0 ppb
3, 4	Standard 1 0.25 ppb
5, 6	Standard 2 1.0 ppb
7, 8	Standard 3 5.0 ppb
9	Control
10	Sample 1
11	Sample 2

Add 200  $\mu$ L of either Standards, Control or Diluted Soil Extract to the **bottom** of each test tube by inserting the pipet tip all the way into the tube without touching the sides or the bottom of the tube.

2

Add 250  $\mu$ L of PCB Enzyme Conjugate down the inside wall of each tube by aiming the pipet tip  $\frac{1}{4}$ " to  $\frac{1}{2}$ " below the tube rim without touching the rim or tube wall with the pipet tip; deliver liquid gently.

3



Add 500  $\mu$ L of **thoroughly mixed** PCB Antibody Coupled Magnetic Particles down the inside wall of each tube by using the technique described in Box 2. **Vortex** for 1 to 2 seconds (at low speed to minimize foaming).

4



**Incubate** 15 minutes at room temperature (15°-30°C).

5



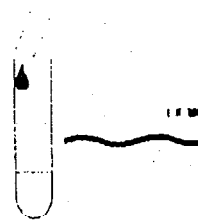
Combine the upper rack with the magnetic base; **press all tubes into base**; allow 2 minutes for the particles to separate.

6



Do **not** separate upper rack from lower base. Using a smooth motion, **invert** the combined rack assembly over a sink and pour out the tube contents: keep inverted and **gently** blot the test tube rims on several layers of paper toweling.

7



Add 1 mL of Washing Solution down the inside wall of each tube. **Vortex** each tube. **Wait 2 minutes**. Using a smooth motion, invert the combined rack assembly over a sink and pour out the tube contents: keep inverted and **gently** blot the test tube rims on several layers of paper toweling.  
**Repeat this step.**

8



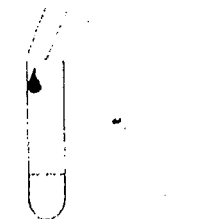
Lift the upper rack (with its tubes) off the magnetic base; add 500  $\mu$ L of Color Reagent down the inside wall of each tube by using the technique described in Box 2. **Vortex** for 1 to 2 seconds (at low speed to minimize foaming).

9



**Incubate** for 20 minutes at room temperature (15 - 30° C). During this period, add 1 mL of Washing Solution into a clean tube for use as an instrument blank in Step 10.

10



Add 500 $\mu$ L of Stopping Solution down the inside wall of each tube by using the technique previously described. **Read results** at 450nm within 15 minutes after adding the Stopping Solution. **Multiply** results of extracted soil samples by the appropriate factor.  
[**Safety Caution:** Stopping Solution contains 0.5% sulfuric acid.]

For Ordering or Technical Assistance Contact:

Strategic Diagnostics, Inc.



Strategic Diagnostics Inc.  
111 Pencader Drive  
Newark, DE 19702  
Phone: (800) 544-8881  
Fax: (302) 456-6782

PCB Rapid Assay Kits  
Part # A00133 30 Tests  
# A00134 100 Tests

RaPID Prep Soil Collection Kit A00127  
RaPID Prep PCB Sample Extraction Kit A00137



*Strategic Diagnostics Inc.*

# Sample Extraction Kit

## User's Guide

### Intended Use

For use in conjunction with the appropriate immunoassay test kit. Each Sample Extraction Kit Contains materials to process twelve (12) soil or wipe samples.

### Principle

The reagents contained in the Sample Extraction Kit have been optimized for fast, efficient removal of compounds from soil or surfaces and convenient preparation of the sample for immunoassay testing at levels of interest to the investigator. The system allows for reliable, convenient and cost effective determinations at the field testing or remediation site.

### Customer Support

If there are any questions regarding this procedure, please call the SDI Technical Services Department at 1-800-544-8881 or (302)-456-6789, before running samples to avoid costly mistakes.

### Extraction Solvents

#### **Extraction Solution - 100% Methanol**

per kit: 12 ampules containing 20 mL each for use with:

- EnSys<sup>®</sup> PCB Soil and Wipe Test Systems (Item # 7020301, 7020601, 7021301 or 7021201)
- EnSys Petro Soil Test Systems (Item # 7042301 and 7043001)
- EnSys PAH Soil Test Systems (Item # 7061301 and 7060501)
- EnSys Penta Soil Test Systems (Item # 7000301)
- PCB RaPID Assay<sup>®</sup> (Item # A00133 and A00134)
- PAH RaPID Assay (Item # A00156 and A00157)
- Carcinogenic PAHs RaPID Assay (Item # A00200 and A00201)
- TNT RaPID Assay (Item # A00186)

#### **Extraction Solution - 100% Methanol**

per kit: 12 ampules containing 10 mL each for use with:

- EnviroGard<sup>®</sup> PCB in Soil and Wipe Test Kits (Item # 7020800, 7021600, 7021500 and 7021600)
- EnviroGard PAH in Soil Test Kit (Item # 7060600)
- EnviroGard Petroleum Hydrocarbons (BTEX) in Soil Test Kits (Item # 7004000)
- EnviroGard Petroleum Hydrocarbons (TPH) in Soil Test Kits (Item # 7042000)
- EnviroGard DDT in Soil Test Kits (Item # 7310000)

**Extraction Solution - 90% Methanol**

per kit: 12 ampules containing 20 mL each for use with:

- EnviroGard Chlordane in Soil test Kit (Item # 7311000)
- EnviroGard Toxaphene in Soil test Kit (Item # 7420000)
- EnviroGard Lindane in Soil Test Kit (Item # 7630000)

**Extraction Solution - 75% Methanol**

per kit: 12 ampules containing 10 mL each for use with:

- BTEX RaPID Assay (Item # A00161 and A00162)

**Extraction Solution - 75% Methanol with Sodium Hydroxide**

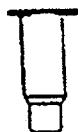
per kit: 12 ampules containing 20 mL each for use with:

- Pentachlorophenol RaPID Assay (Item # A00110 and A00111)

**Extraction Solution - 100% Methanol with Surfactant**

per kit: 12 ampules containing 10 mL each for use with:

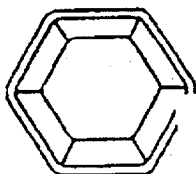
- Cyclodienes RaPID Assay (Item # A00216)

**Description of Contents**

Filtration barrel



Filtration plunger



Weigh Boat



Tooth pick



Extraction jar



Wooden spatula



Ampule cracker



Template

**Filter Modules**

per kit: 12 filter plungers and barrels

**Wooden Spatulas**

per kit: 12 each

**Weigh Canoes**

per kit: 12 each

**Disposable Transfer Pipettes**

per kit: 12 each

**Extraction Jars**

per kit: 12 each with 3 bearings per jar

**Ampule Crackers**

per kit: 3 each

**Wipe Template**

per kit: 12 each 10 cm by 10 cm plastic templates (PCB Wipe Kit only)

**Gauze Wipes**

per kit: 12 each (PCB Wipe Kit only)

**Protective Gloves**

per kit: 24 each (PCB Wipe Kit Only)

## Sample Dilution

### RaPID Assay Test Systems

- BTEX Extract Diluent: 12 vials containing 4.5 mL each (Item #100654).
- PCB Extract Diluent: 12 vials containing 25 mL each. One (1) 25  $\mu$ L disposable pipet with 12 tips (Item #100538).
- Pentachlorophenol Extract Diluent: 12 vials containing 25 mL each. One (1) 50  $\mu$ L disposable pipet with 12 tips (Item #100479).
- PAH Extract Diluent: 12 vials containing 12.25 mL each (Item #100623).
- Carcinogenic PAHs Extract Diluent: 12 vials containing 9.8 mL each (Item #100798).
- TNT Extract Diluent: 12 vials containing 25 mL each. One (1) 50  $\mu$ L disposable pipet with 12 tips (Item #100745).
- Cyclodienes Extract Diluent: 12 vials containing 12.25 mL each (Item #101024).

### EnSys Soil Test Systems

- Dilution ampules provided dependent upon detection levels of interest.

### EnviroGard Soil Test Systems

- No additional dilution materials required.

## Reagent Storage and Stability

Store all reagents and components in a dry well ventilated area at 2-30°C.

Reagents may be used until the expiration date shown on the vials.

Consult local, state and federal regulations for proper disposal of all reagents.

## Materials Not Provided

In addition to the materials provided, the following items will be necessary for the procedure:

- stopwatch or clock with second hand
- permanent marking pen
- protective gloves
- digital balance (available from SDI, Item # A00131)

## Sample Information

This kit was validated for use with soil samples. Other types of sample matrices and solid wastes may require different procedures to efficiently extract compounds of interest. Contact SDI's Technical Services Department for application guidance.

## Procedural Notes and Precautions

Do not use any reagent beyond its stated shelf life.

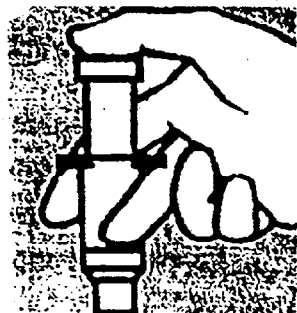
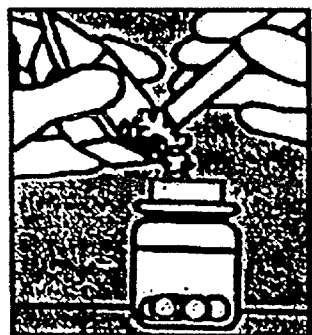
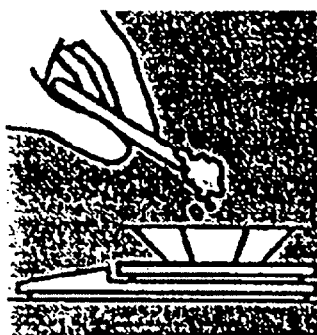
Continuous agitation of the soil sample in the presence of the extraction solution for the prescribed time is important for good extraction efficiency. Use of a timer or stopwatch to assure adequate shaking time is recommended.

Avoid contact of extraction solution (methanol) with skin and mucous membranes. If this reagent comes in contact with skin wash with water.

## Limitations

The Sample Extraction Kit, when used in conjunction with the appropriate test kit, will provide screening results. Results may need to be confirmed by a non-immunological method.

## Soil Extraction Procedure



## WEIGH SAMPLE

1. Place unused weigh canoe on pan balance.
2. Press ON/MEMORY button on pan balance. Balance will beep and display 0.0.
3. Weigh out  $10 \pm 0.1$  grams of sample using the wooden spatula.
4. If balance turns off prior to completing weighing, use empty weigh canoe to re-tare then continue.
5. Repeat steps 1-4 for each sample to be tested.

## EXTRACTION

1. Uncap extraction jar and place on flat surface. Using a wooden spatula, transfer 10 grams of sample from the weigh boat into the extraction jar.
2. Open solvent ampule and pour the entire contents into the extraction jar.
3. Recap the extraction jar and shake vigorously for one (1) minute.
4. Allow to settle for one (1) minute or until a clear solvent layer is observed above the sample.
5. Repeat steps 1-4 for each sample to be tested.

## FILTRATION

1. Insert bulb pipet into top (liquid) layer in extraction jar and draw up sample. Transfer at least  $\frac{1}{2}$  bulb capacity into the filtration barrel. *Do not use more than one full bulb.*
2. Press plunger firmly into barrel until adequate filtered sample is available or unit snaps together. Place on flat surface.
3. Repeat steps 1-3 for each sample to be tested.

## DILUTION

EnviroGard - Use the filtered extract as "SAMPLE" in the User's Guide Procedure.

EnSys - If the instructions start with Phase 1 *Extraction and Preparation of the Sample* in the User's Guide, skip to Phase 2 *Sample and Standard Preparation* and follow the remainder of the assay procedure and data interpretation. If the instructions start at Phase 1 *Sample & Standard Preparation*, continue with the instructions, as written.

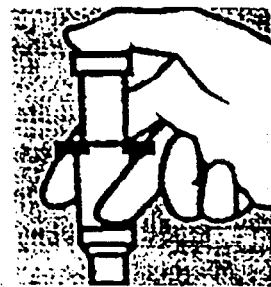
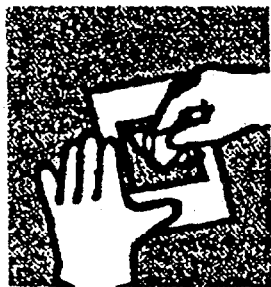
**Note:** Kit may contain additional ampules in order to achieve your test levels. Always transfer filtered sample to the dilution ampule labeled with the lowest PPM level and then transfer from this ampule to the next higher level dilution ampule.

**RaPID Assay** - Dilute the filtered extract into the appropriate Extract Diluent as described below or follow customized dilution procedure provided by the SDI Technical Services Department.

## RaPID Assay Dilution

Contaminant	Extract Volume ( $\mu$ L)	Extract Diluent (mL)	Test Range (ppm)
PCB	25	25	0.5 to 10.0 (Aroclor 1254)
PAH	250	12.25	0.2 to 5.0 (Phenanthrene)
caPAH	200	9.8	0.01 to 0.5 (Benzo[a]pyrene)
BTEX/TPH	500	4.5	0.9 to 30 (Total BTEX)
Pentachlorophenol	50	25	0.1 to 10.0 (PCP)
TNT	50	25	0.25 to 5.0 (TNT)
Cyclodienes	250	12.5	0.1 to 2.0 (Dieldrin)

## Wipe Extraction Procedure



## WIPE SAMPLE

1. Wearing the protective gloves provided, uncap the extraction jar.
2. Using an ampule cracker, open solvent ampule and pour the entire contents into the extraction jar.
3. Soak gauze pad in extraction jar containing solvent.
4. Remove gauze wipe from solvent and squeeze excess from pad back into extraction jar.
5. Hold clean template on surface to be wiped.
6. Wipe entire exposed area for 15-20 seconds. Wipe should be damp when finished.
7. Place wipe back into same extraction jar and cap tightly.
8. Remove and discard protective gloves.
9. Repeat steps 1-8 for each sample to be tested.

## EXTRACTION

1. Shake each jar vigorously for one (1) minute.
2. Repeat step 1 for each sample to be tested.

## FILTRATION

1. Disassemble filtration plunger from filtration barrel.
2. Insert bulb pipet into top (liquid) layer in extraction jar and draw up sample. Transfer at least  $\frac{1}{2}$  bulb capacity into the filtration barrel. *Do not use more than one full bulb.*
3. Press plunger firmly into barrel until adequate filtered sample is available or unit snaps together. Place on flat surface.
4. Repeat steps 1-3 for each sample to be tested.





## Product Profile

## General Description

Polychlorinated biphenyls (PCBs) were marketed under the trade name Aroclor® from 1930 to 1977 for use in transformers, capacitors, printing inks, paints, pesticides and many other applications. The Toxic Substances Control Act (TOSCA, 1976), declared PCBs to be toxic and carcinogenic and banned manufacture.

PCBs are classified by the US EPA as Group B2 contaminants, a probable human carcinogen based on sufficient evidence in animals and inadequate data in human studies (US EPA, 1991). PCBs do not readily degrade in the environment and tend to bioaccumulate. The EPA has set a Maximum Contaminant Level for PCB in drinking water of 0.5 ppb and various levels in soil.

Current EPA-approved methods for the detection of PCBs are costly and require lengthy sample preparation, large volume extraction and solvent exchange. The PCB RaPID Assay® eliminates the need for clean-up steps and GC/ECD instrumentation.

The PCB RaPID Assay applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of PCBs. ELISAs use selective antibodies which are attached to solid supports, in combination with sensitive enzyme reactions. The immunochemical reaction provides high selectivity due to the extraordinary discriminatory capabilities of antibodies. The powerful catalytic ability of the enzyme provides highly sensitive detection. These features produce an analytical system capable of detecting very low levels of chemicals.

## PCB RaPID Assay®



## Features

- Rapid** – 60 results in less than 45 minutes.
- Precise** – within and between assay %CV <5% at 4.4 ppb.
- Accurate** – highly selective immunochemical method.
- Efficient** – rapid results can cut costs by allowing better personnel and equipment utilization.
- Sensitive** – least detectable dose in water of 0.2 ppb as Aroclor 1254 (90% B/Bo).
- Test Range** – water: 0.5 to 10.0 ppb as Aroclor 1254.  
soil: 0.5 to 10.00 ppm.

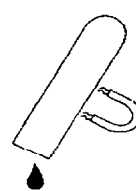
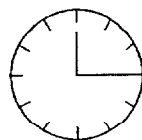
## PCB RaPID Assay® — Assay Protocol



1. Add 200  $\mu$ L of prepared sample, 250  $\mu$ L enzyme conjugate, and 500  $\mu$ L antibody coupled magnetic particles.



2. Incubate for 15 minutes.



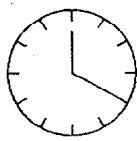
3. Using the RaPID magnetic separator, decant, wash and vortex (2x).



4. Add 500  $\mu$ L color reagent.



5. Incubate 20 minutes. Blue color develops.



← Blue



6. Stop the reaction and read color at 450 nm. Solution turns yellow.

← Yellow

## Performance

### Specificity

The proprietary antibody used in this assay was developed to detect PCBs. The cross-reactivity with different Aroclors can be expressed as the least detectable dose (LDD) which is estimated at 90% B/B0.

Compound	LDD Water (ppb)	LDD Soil (ppm)	50% B/B0 Water (ppb)	50% B/B0 Soil (ppm)
Aroclor 1254	0.20	0.50	3.60	3.60
Aroclor 1260	0.20	0.30	2.30	2.30
Aroclor 1248	0.22	0.42	4.22	4.22
Aroclor 1242	0.34	0.80	8.80	8.80
Aroclor 1262	0.36	0.64	4.74	4.74
Aroclor 1232	0.84	2.24	18.76	18.76
Aroclor 1268	0.92	2.30	21.80	21.80
Aroclor 1016	0.94	2.70	25.60	25.60
Aroclor 1221	13.54	26.60	162.60	162.60

### Precision

Water samples were fortified with Aroclor 1254 at different levels and assayed in singlicate five times over five days. The following results were obtained (n=25):

Sample #	1	2	3	4
Mean	0.86	3.10	4.36	8.04
% CV <sup>a</sup>	8.5	6.2	4.6	4.9
% CV <sup>b</sup>	15.7	6.1	0.6	2.5

within assay

<sup>a</sup> between assay

### Recovery

Four water samples, taken from a small creek, local pond, well and municipal water source were fortified with various levels of Aroclor 1254 and assayed with this system. The following results were obtained (n=12):

Spike (ppb)	Recovery Mean $\pm$ S.D.	%
1.0	0.86 $\pm$ 0.08	86
3.0	3.18 $\pm$ 0.28	106
4.0	4.32 $\pm$ 0.36	108
8.0	7.68 $\pm$ 0.66	96
Average		99

### Solvent Tolerances

The following solvents do not interfere with this assay when their concentration in the sample is at, or lower, than those listed.

Solvent	Maximum Conc. Tolerated
Acetone	5%
Acetonitrile	2%
DMF	5%
Methanol	10%
Methylene Chloride	0.2%

## Results

When using the RPA-I RaPID Analyzer™, results are reported in ppb PCB. If read in a standard spectrophotometer, results from the calibrators are plotted on graph paper and used to determine final results. It is recommended that a control be included in each run. A positive control (3.0 ppb) is supplied with the PCB RaPID® Assay kit.

As with any analytical technique (GC, HPLC, etc.), positive results requiring some action should be confirmed by an alternate technology.

## Ordering Information

### PCB Products

RaPID Assay kit, 30 and 100 tests  
Sample Diluent, 100 mL  
Proficiency Samples  
Sample Extraction kit, 20 tests

For ordering or technical  
assistance contact:

Sales Department  
Ohmicron Environmental Diagnostics, Inc.  
1-800-544-8881  
1-215-860-5115  
Fax 1-215-860-5213



# RaPID Assays®

## PCB

### • Intended Use

For detection of Polychlorinated Biphenyls (PCBs). Please refer to the attached specific procedures for water (groundwater, surface water, well water, effluent), and soil. Application procedures for other sample matrices can be obtained from Ohmicron.

### • Principle

The PCB RaPID Assay® applies the principles of enzyme linked immunosorbent assay (ELISA) to the determination of PCB. The sample to be tested is added, along with an enzyme conjugate, to a disposable test tube, followed by paramagnetic particles with antibodies specific to PCB attached. Both the PCB (which may be in the sample) and the enzyme labeled PCB (the enzyme conjugate) compete for antibody binding sites on the magnetic particles. At the end of an incubation period, a magnetic field is applied to hold the paramagnetic particles (with PCB and labeled PCB analog bound to the antibodies on the particles, in proportion to their original concentration) in the tube and allow the unbound reagents to be decanted. After decanting, the particles are washed with Washing Solution.

The presence of PCB is detected by adding the enzyme substrate (hydrogen peroxide) and the chromogen (3,3',5,5'-tetramethylbenzidine). The enzyme-labeled PCB analog bound to the PCB antibody catalyzes the conversion of the substrate/chromogen mixture to a colored product. After an incubation period, the reaction is stopped and stabilized by the addition of acid. Since the labeled PCB (conjugate) was in competition with the unlabeled PCB (sample) for the antibody sites, the color developed is inversely proportional to the concentration of PCB in the sample.

### • Reagents

#### 1. PCB Antibody Coupled Paramagnetic Particles

The PCB antibody (rabbit anti-PCB) is covalently bound to paramagnetic particles, which are suspended in buffered saline containing preservative and stabilizers.

30 test kit: one 20 mL vial  
100 test kit: one 85 mL vial

#### 2. PCB Enzyme Conjugate

The horseradish peroxidase (HRP) labeled PCB analog is diluted in buffered saline containing preservative and stabilizers.

30 test kit: one 10 mL vial  
100 test kit: one 35 mL vial

#### 3. PCB Standards

Three concentrations (0.25, 1.0, 5.0 ppb) of PCB (as Aroclor 1254) standards in buffered saline containing preservative and stabilizers are supplied. Each vial contains 2.0 mL.

#### 4. Control

A concentration (approximately 3 ppb) of PCB (as Aroclor 1254) in buffered saline containing preservative and stabilizers. A 2.0 mL volume is supplied in one vial.

#### 5. Diluent/Zero Standard

Buffered saline containing preservative and stabilizers without any detectable PCB.

30 test kit: one 10 mL vial  
100 test kit: one 35 mL vial

#### 6. Color Solution

A solution of hydrogen peroxide and 3,3',5,5'-tetramethylbenzidine in an organic base.

30 test kit: one 20 mL vial  
100 test kit: one 85 mL vial

#### 7. Stopping Solution

A solution of sulfuric acid (0.5%).

30 test kit: one 20 mL vial  
100 test kit: one 80 mL vial

#### 8. Washing Solution

Preserved deionized water.

30 test kit: one 70 mL vial  
100 test kit: one 250 mL vial

#### 9. Test Tubes

Polystyrene tubes (38) are packed in a box.

30 test kit: one 38 tube box  
100 test kit: three 38 tube boxes

### • Reagent Storage and Stability

Store all reagents at 2-8°C. Do not freeze. Reagents may be used until the expiration date on the box. The test tubes require no special storage condition and may be stored separately from the reagents to conserve refrigerator space.

Consult state, local and federal regulations for proper disposal of all reagents.

### • Materials Required but Not Provided

In addition to the reagents provided, the following items are essential for the performance of the test:

Pipets\* Precision pipets capable of delivering 200, 250 and 500 µL and a 1.0 mL repeating pipet.

Vortex Mixer\* Thermolyne Maxi Mix, Scientific Industries Vortex Genie, or equivalent

Magnetic Separation Rack\*

RPA-1™ RaPID Analyzer\* or equivalent photometer capable of readings at 450 nm

\* These items are available from Ohmicron.

### • Sample Information

Refer to sample preparation information contained under individual procedure (i.e. water, soil) or application notes.

Samples which have been preserved with monochloroacetic acid or other acids, should be neutralized with strong base e.g. 6N NaOH, prior to assay.

If the PCB concentration of a sample exceeds 5 ppb, the sample is subject to repeat testing using a diluted sample. A ten-fold or greater dilution of the sample is recommended with an appropriate amount of Diluent/Zero Standard or Sample Diluent. For example, in a separate test tube make a ten-fold dilution by adding 100 µL of the sample to 900 µL of Diluent/Zero Standard. Mix thoroughly before assaying. Perform the assay according to the Assay Procedure and obtain final results by multiplying the value obtained by the dilution factor e.g. 10.

The presence of the following substances up to 250 ppm were found to have no significant effect on PCB RaPID Assay results: copper, nickel, zinc, mercury, manganese, phosphate, sulfate, sulfite, magnesium, calcium, nitrate and thiosulfate. Humic acid up to 25 ppm and iron to 100 ppm were found to have no significant effect. In addition, sodium chloride concentrations up to 1.0 M showed no effect on results.

### • Reagent Preparation

All reagents must be allowed to come to room temperature and the antibody coupled paramagnetic particles should be mixed thoroughly before use.

### • Procedural Notes and Precautions

As with all immunoassays, a consistent technique is the key to optimal performance. To obtain the greatest precision, be sure to treat each tube in an identical manner.

Add reagents directly to the bottom of the tube while avoiding contact between the reagents and the pipet tip. This will help assure consistent quantities of reagent in the test mixture.

Avoid cross-contaminations and carryover of reagents by using clean pipets for each sample addition and by avoiding contact between reagent droplets on the tubes and pipet tips.

Avoid foam formation during vortexing.

which contains the magnets used to attract the antibody coupled paramagnetic particles. During incubations the upper rack is removed from the lower separator so that the paramagnetic particles remain suspended during the incubation. For separation steps, the rack and the separator are combined to pull the paramagnetic particles to the sides of the tubes.

To obtain optimum assay precision, it is important to perform the separation steps carefully and consistently. Decant the rack by slowly inverting away from the separator using a smooth turning action so the liquid flows consistently along only one side of the test tube. While still inverted, place the rack on an absorbent pad and allow to drain. Lifting the rack and replacing gently onto the pad several times will ensure complete removal of the liquid from the rim of the tube (technique is demonstrated on training video, available from Ohmicron).

Mix the antibody coupled paramagnetic particles just prior to pipetting.

Standard and Control vials should remain capped when not in use, to prevent evaporation.

Do not use any reagents beyond their stated shelf life.

Avoid contact of Stopping Solution (sulfuric acid) with skin and mucous membranes. If this reagent comes in contact with skin, wash with water.

### • Limitations

The PCB RaPID Assay will detect PCBs to different degrees. Refer to specificity table for data on various Aroclors and congeners. The PCB RaPID Assay kit provides screening results. As with any analytical technique (GC, HPLC, etc.) positive results requiring some action should be confirmed by an alternative method.

The total time required for pipetting the magnetic particles should be kept to two (2) minutes or less, therefore the total number of tubes that can be assayed in a run should be adjusted accordingly.

### • Quality Control

A control solution at approximately 3 ppb of PCB (as Aroclor 1254) is provided with the PCB RaPID Assay kit. It is recommended that it be included in every run and treated in the same manner as unknown samples. Acceptable limits should be established by each laboratory.

### • Assay Procedure

Read Reagent Preparation, Procedural Notes and Precautions before proceeding.

1. Perform the appropriate sample preparation according to the attached water or soil procedure. For any other sample matrices refer to specific procedures available from Ohmicron.
2. Label test tubes for standards, control, and samples.

Tube Number	Contents of Tube
1,2	Diluent/Zero Standard, 0 ppb
3,4	Standard 1, 0.25 ppb
5,6	Standard 2, 1.0 ppb
7,8	Standard 3, 5.0 ppb
9	Control
10	Sample 1
11	Sample 2
12	Sample 3

3. Add 200  $\mu$ L of the appropriate standard, control, or sample.
4. Add 250  $\mu$ L of PCB Enzyme Conjugate to each tube.
5. Mix the PCB Antibody Coupled Paramagnetic Particles thoroughly and add 500  $\mu$ L to each tube.
6. Vortex for 1 to 2 seconds minimizing foaming.

minutes.

8. Decant and gently blot all tubes briefly in a consistent manner.
10. Add 1 mL of Washing Solution to each tube and vortex tubes for 1-2 seconds. Return tubes and allow to remain in the magnetic separation unit for two (2) minutes.
11. Decant and gently blot all tubes briefly in a consistent manner.
12. Repeat Steps 10 and 11 an additional time.
13. Remove the rack from the separator and add 500  $\mu$ L of Color Solution to each tube.
14. Vortex for 1 to 2 seconds minimizing foaming.
15. Incubate for 20 minutes at room temperature.
16. Add 500  $\mu$ L of Stopping Solution to each tube.
17. Add 1 mL Washing Solution to a clean test tube. Use as blank in Step 18.
18. Read results at 450 nm within 15 minutes after adding the Stopping Solution.

### • Results

#### Manual Calculations

1. Calculate the mean absorbance value for each of the standards.
2. Calculate the %B/B<sub>0</sub> for each standard by dividing the mean absorbance value for the standard by the mean absorbance value for the Diluent/Zero Standard.
3. Construct a standard curve by plotting the %B/B<sub>0</sub> for each standard on vertical logit (Y) axis versus the corresponding PCB concentration on horizontal logarithmic (X) axis on the graph paper provided.
4. %B/B<sub>0</sub> for controls and samples will then yield levels in ppb of PCB by interpolation using the standard curve.  
(Contact Ohmicron for detailed application information on specific photometers.)

#### RPA-1 RaPID Analyzer

Using the RPA-1 RaPID Analyzer, calibration curves can be automatically calculated and stored. Refer to the RPA-1 operating manual for detailed instructions. To obtain results from the PCB RaPID Assay on the RPA-1 the following parameter settings are recommended:

Date Reduct : Lin. Regression  
Xformation : LnLogitB  
Read Mode : Absorbance  
Wavelength : 450 nm  
Units : PPB  
# Rgt Blk : 0

#### Calibrators:

# of Cals : 4  
# of Repts : 2

#### Concentrations:

#1: 0.00 PPB  
#2: 0.25 PPB  
#3: 1.00 PPB  
#4: 5.00 PPB

Range : 0.10 - 5.00  
Correlation : 0.990  
Rep. %CV : 10%

### • Expected Results

Refer to the expected result section in the appropriate application note or procedure.

### • Performance Data

#### Sensitivity

The PCB RaPID Assay has an estimated minimum detectable concentration, based on a 90% B/B<sub>0</sub> of 100 ppt. Refer to appropriate application notes or procedures for sensitivity in specific sample matrices.

CAN BE EXPRESSED AS THE MEAN OF SEVERAL READINGS WHICH IS ESTIMATED AT 90% B/B<sub>0</sub>, or as the dose required to displace 50% (50% B/B<sub>0</sub>).

Compound	LDO (ppb)	50% B/B <sub>0</sub> (ppb)
Aroclor 1254	0.10	1.80
Aroclor 1280	0.10	1.15
Aroclor 1248	0.11	2.11
Aroclor 1242	0.17	4.40
Aroclor 1262	0.18	2.37
Aroclor 1232	0.42	9.38
Aroclor 1268	0.48	10.9
Aroclor 1016	0.47	12.9
Aroclor 1221	8.77	81.3

The following compounds demonstrated no reactivity in the PCB RaPID Assay at concentrations up to 10,000 ppb: Biphenyl, 2,5-Dichlorophenol, 2,3,5-Trichlorophenol, Di-n-octyl-phthalate.

### • Assistance

For ordering or technical assistance contact:

Ohmicron Environmental Diagnostics  
Sales Department  
Newtown, Pennsylvania 18840  
(800)544-8881 • Fax (215)880-5213

### • Availability

Ohmicron

PCB RaPID Assay  
30 Test Kit  
100 Test Kit  
PCB Sample Diluent  
PCB Proficiency Samples  
RaPID Prep™ Soil Collection Kit  
RaPID Prep PCB Sample Extraction Kit



# PCB in Soil

## • Intended Use

For detection of Polychlorinated Biphenyls (PCBs) in soil.

## • Materials Required but Not Provided

RaPID Prep™ Soil Collection Kit and PCB Sample Extraction Kit.

## • Procedural Notes and Precautions

Prepare soil samples for analysis according to the procedure given in the PCB Sample Extraction Kit. then, follow the immunoassay procedure as described in the PCB RaPID Assay® Kit package insert.

As with all immunoassays, a consistent technique is the key to optimal performance. To obtain the greatest precision, be sure to treat each tube in an identical manner.

Add reagents directly to the bottom of the tube while avoiding contact between the reagents and the pipet tip. This will help assure consistent quantities of reagent in the test mixture.

Avoid cross-contaminations and carryover of reagents by using clean pipets for each sample addition and by avoiding contact between reagent droplets on the tubes and pipet tips.

## • Quality Control

A control solution at approximately 3 ppb of PCB (as Aroclor 1254) is provided with the PCB RaPID Assay kit. It is recommended that it be included in every run and treated in the same manner as unknown samples. Once the control results are corrected for the dilution factors (see Results section) an acceptable result should be 2000 times the value stated on the vial, i.e. 6.0 +/- 1.2 ppm.

## • Results

Multiply the sample and control results by the appropriate dilution factor introduced by the collection, extraction and extract dilution steps. When the collection/extraction/dilution procedure described in the PCB Sample Extraction Kit is performed with a ten gram soil sample, the RaPID Assay result is multiplied by 2000 to determine the soil PCB concentration. Alternatively, program the RPA-1 Analyzer as listed below to automatically correct for this dilution factor.

Using the RPA-1™ RaPID Analyzer, calibration curves can be automatically calculated and stored. Refer to the RPA-1 operating manual for detailed instructions. To obtain results from the PCB RaPID Assay on the RPA-1 the following parameter settings are recommended:

Date Reagent : Lin. Regression  
Xformation : Ln/Log10  
Read Mode : Absorbance  
Wavelength : 450 nm  
Units : PPM  
# Rgt Bk : 0

### Calibrators:

# of Cals : 4  
# of Repts : 2

### Concentrations:

#1: 0.00 PPM  
#2: 0.50 PPM  
#3: 2.00 PPM  
#4: 10.00 PPM

Range : 0.20 - 10.00  
Correlation : 0.990  
Rep. %CV : 10%

## • Expected Results

In a study with 16 samples including both field contaminated soil and analytically spiked soils samples, the RaPID Prep PCB Sample Extraction Kit results were shown to correlate well with a gas chromatographic method ( $r = 0.805$ ).

## • Performance Data

### Range of Detection

The PCB RaPID Assay has a range of detection in soil of 500 ppb to 10 ppm when used in conjunction with the PCB Sample Extraction Kit.

### Recovery

PCB recoveries will vary depending on soil type, retention mechanism, solvent and extraction apparatus used, length of extraction period and levels of potentially interfering substances in the soil.

Two (2) soils of the clay and loam type were fortified with PCB (Aroclor 1254) to final soil concentrations of 5, 50 and 500 ppm. Average recovery of added PCB was 85%. Results ranged from 74 to 101%.

### Precision

The overall coefficient of variation (%CV) for PCB measurement in soil spiked at 4 ppm using the RaPID Prep components and PCB RaPID Assay is less than 20%. This represents the amount of variability expected when a homogeneous soil sample undergoes ten replicate collections, extractions and dilutions generating ten immunoassay results from a single run.

Method	Sample Collection	
	by weight	by volume
# of replicates	10	10
mean results (ppm)	3.20	3.47
% CV	15.2	18.3

## • Assistance

For ordering or technical assistance contact:  
Ohmicron Environmental Diagnostics  
Sales Department  
Newtown, Pennsylvania 18940  
(800)544-8881 \* Fax(215)860-5213

## • Availability

### Ohmicron

PCB RaPID Assay  
30 Test Kit  
100 Test Kit  
PCB Sample Diluent  
PCB Proficiency Samples  
RaPID Prep Soil Collection Kit  
RaPID Prep PCB Sample Extraction Kit

**APPENDIX D**  
**MONITORING WELL INSTALLATION**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
MONITORING WELL INSTALLATION**

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**Page 1 of 8  
SOP Number: F103  
Effective Date: 04/94**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Well Installation
5.2	Drive Points
5.3	Surface Completion
5.4	Well Development
5.5	Contaminated Materials Handling
5.6	Well Construction Logs
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

**ATTACHMENT A -- MONITORING WELL CONSTRUCTION**

**ATTACHMENT B -- ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

**ATTACHMENT C -- FIELD TEST BORING RECORD AND FIELD WELL CONSTRUCTION  
FORMS**

## MONITORING WELL INSTALLATION

### 1.0 PURPOSE

The purpose of this procedure is to provide general guidance and reference material regarding the installation of monitoring wells at various sites.

### 2.0 SCOPE

This SOP describes the methods of installing a groundwater monitoring well, and creating a Monitoring Well Installation Record. This SOP does not discuss drilling, soil sampling, borehole logging or related activities. These other activities are discussed in SOPs F102 and F101 entitled Soil and Rock Sample Acquisition, and Borehole and Sample Logging, respectively.

### 3.0 DEFINITIONS

Monitoring Well – A monitoring well is a well which is properly screened, cased, and sealed to intercept a discrete zone of the subsurface, and is capable of providing a groundwater level and sample representative of the zone being monitored.

Piezometer – A piezometer is a pipe or tube inserted into an aquifer or other water-bearing zone, open to water flow at the bottom, open to the atmosphere at the top, and used to measure water level elevations. Piezometers are not used for the collection of groundwater quality samples or aquifer characteristic data other than water level elevations.

Drive Point – A monitoring well which includes a screen casing and hardened point fabricated from stainless steel that is driven into the soil to complete the well. The drive point can also be installed by hand augering to try to formulate a sand pack around the screen.

### 4.0 RESPONSIBILITIES

Project Manager – It is the responsibility of the Project Manager to ensure that field personnel installing monitoring wells are familiar with these procedures. The Project Manager also is responsible for ensuring that all appropriate documents (e.g., test boring logs, monitoring well construction logs, etc.) have been correctly and completely filled out by the drilling inspector.

Field Team Leader – The Field Team Leader is responsible for the overall supervision of all drilling, boring and well installation activities, and for ensuring that the well is completely and correctly installed and logged. The Field Team Leader also is responsible for ensuring that all drilling inspectors have been briefed on these procedures. The Field Team Leader is responsible to provide copies of the well construction logs and field log books to the Project File via the Project Manager on a weekly basis, unless otherwise specified by the Project Manager.



Drilling Inspector (Site Geologist) – The Drilling Inspector or Site Geologist is responsible for the direct supervision of drilling and well installation activities. It is the Drilling Inspector's responsibility to record details of the well installation, document subsurface conditions, complete the appropriate forms, supervise the drilling crew (or drilling supervisor), and record quantities of the drillers billable labor and materials.

## **5.0 PROCEDURES**

The objectives for the use of each monitoring well and of the entire array of wells must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, may require different types of construction. During all phases of the well design (both office and field), attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used.

The objectives for installing monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for groundwater contamination.
- Determining aquifer characteristics (e.g., hydraulic conductivity).
- Facilitating site remediation via injection or recovery.

In cases where only the groundwater flow direction or velocity needs to be determined, cluster piezometers or wells (i.e., wells completed to different depths in different boreholes at one data collection station) may be used. For groundwater quality monitoring or aquifer characteristic determination, monitoring wells or cluster wells should be used. In areas that are inaccessible to drill rigs (i.e., unstable surface soils), driven wells (drive points) may be used.

Siting of monitoring wells shall be performed after a preliminary estimation of groundwater flow direction. Typically, site visits, topographic mapping, regional/local hydrogeologic information, previously installed piezometers or monitoring wells, or information supplied by local drilling companies will provide information for siting wells. Flexibility should be maintained, so that well locations may be modified during the field investigation to account for site conditions (e.g., underground utilities). The elevation and horizontal location of all monitoring wells shall be determined through a site survey upon completion of well installation.

### **5.1 Well Installation**

The methods discussed in this section are applicable to shallow, small diameter monitoring wells. Project-specific modifications to these methods shall be documented in the Sampling and Analysis Plan. These modifications may include larger diameter shallow wells, extraction wells, deep monitoring wells requiring surface casing and other specially constructed well types. Guidelines for monitoring well construction are given in Attachment A. Typical shallow monitoring well construction details are shown in Figures A-1 and A-2 in Attachment A for wells with flush-mounted and stick-up wells, respectively.

Note that these procedures discuss well installation using a PVC screen and riser pipe. Other materials such as stainless steel or Teflon also are available. Generally PVC is less expensive and easier to work with than either stainless steel or Teflon. A disadvantage to using PVC is the potential for degradation of the materials,

or release (leaching) of constituents into the groundwater. Because of these concerns, justification for using PVC must be developed on a project-specific basis. The checklist shown in Attachment B provides a format for developing this justification.

Upon completion of each boring (refer to SOP F101 and F102 for Borehole and Sample Logging, and Soil and Rock Sample Acquisition, respectively), monitoring wells will usually be constructed using either 2-inch or 4-inch inside diameter (I.D.) screen and riser. Schedule 40 PVC, threaded, flush-joint casings with a continuous #10 slot (0.010-inch), threaded, flush-joint PVC screen. A larger or smaller diameter screen may be used to accommodate site-specific geologic conditions. If wells are to be constructed over 100 feet in length, or in high traffic areas, or under other unusual conditions, Schedule 80 PVC may be used because of its greater strength.

An appropriate length of well screen shall be installed in each boring. The length of screen typically varies from 1 to 20 feet depending on site-specific conditions. For light nonaqueous phase liquid (LNAPL) applications, the screen should be installed such that at least 2 feet of screen is above the water table and the remainder of the screen extends below the water surface so that free product can enter the well. Should very shallow water table conditions be encountered, the screened interval in both the saturated and unsaturated zones may be reduced to ensure an adequate well seal above the screened interval. If this situation is expected, it should be addressed in the project plans, as necessary. A 6-inch section of PVC casing may be placed at the bottom of each screen to act as a settling cup for fines which may pass through the filter pack and screen.

Other applications may call for different screen placement depending on the zone to be monitored and the expected contaminants. For example, monitoring for dense non-aqueous phase liquids (DNAPLs) may require placing the screened interval in a "sump" at the base of the aquifer. Depending on the purpose of the monitoring well, the riser pipe may extend from the top of the screened interval to either 6 inches below the ground surface (for flush-mounted wells) to between approximately one and 2 feet above the ground surface for wells completed with stick-up.

The annular space around the screen is to be successively backfilled with a well graded quartz-sand, sodium bentonite and cement/bentonite grout as the hollow-stem augers are being withdrawn from the borehole. The sand size used in well construction will be appropriate for the formation monitored by the well. Sand shall carefully be placed from the bottom of the boring to a minimum of 2 feet (or 20 percent of the total screen length) above the top of the screened interval. A lesser distance above the top of the screened interval may be packed with sand if the well is very shallow to allow for placement of sealing materials.

A sodium bentonite seal at least two-foot thick shall be placed above the sand pack. For deep wells, a bentonite slurry may be more appropriate than pellets due to problems with bridging in the annular space.

The annular space above the bentonite seal will be backfilled with a cement-bentonite grout consisting of 3 to 4 percent bentonite powder (by dry weight) or equivalent grout. The grout mixture shall be specified in the project plans. The grout will be tremied into the annular space greater than 20 feet high. If the annular space is less than 20 feet high, the grout may be poured directly into the annular space.

The depth intervals of all backfill materials shall be measured with a weighted measuring tape to the nearest 0.1 foot and recorded on the Field Well Construction Record (Attachment C) or in a field logbook.

## **5.2     Drive Points**

Drive points may be constructed in one of two ways. If the drive point is hammered into place, no other well construction will take place. (Note that the well assembly is fabricated from 2-inch diameter stainless steel and includes a screen casing, and hardened point). The drive points will be sampled according to SOP F104, "Groundwater Sample Acquisition."

## **5.3     Surface Completion**

There are several methods for surface completion of monitoring wells. Two such methods are discussed below.

The first method considers wells completed with stick-up. The aboveground section of the PVC riser pipe will be protected by installation of a 4- or 6-inch diameter, 5-foot long steel casing into the cement grout with locking cap and lock. The bottom of the surface casing will be placed at a minimum of 2- 1/2, but not more than 3- 1/2 feet below the ground surface. For very shallow wells, a steel casing of less than five-feet in length may be used, as space permits. The protective steel casing shall not fully penetrate the bentonite seal. A concrete apron shall be constructed around the steel casing.

The second method considers flush-mounted wells, typically installed where a stick-up installation would present a traffic hazard. The monitoring well shall be completed at the surface using a "flush" mount type cover. If the well is installed through a paved or concrete surface, the annular space shall be grouted to a depth of at least 2.5-feet and the well shall be finished with a concrete collar. If the well has not been installed through a paved or concrete surface, the well shall be completed by construction of a concrete apron. The concrete shall be crowned to meet the finished grade of the surrounding pavement, as required. If appropriate, the vault around the buried wellhead will have a water drain to the surrounding soil and a watertight cover.

Project specific tasks may require that all monitoring wells shall be labeled by metal stamping on the exterior of the protective steel casing or locking cap. A sign reading "Not For Potable Use or Disposal" also shall be firmly attached to each well. Alternately, well identification information may be stamped on a metal plate and attached to the well protective steel casing or embedded in the concrete apron, if appropriate.

## **5.4     Well Development**

There are two stages of well development, initial and sampling. Sampling development is described in SOP F104, Groundwater Sample Acquisition. Initial development takes place after the completion materials have stabilized, as the last part of well construction.

The purposes of the initial development are to stabilize and increase the permeability of the filter pack around the well screen, to restore the permeability of the formation which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered the well or filter pack during installation. The selection of the well development method typically is based on drilling methods, well construction and installation details, and the characteristics of the formation. Any equipment that is introduced into the well during development shall be decontaminated in accordance with the SOP F501,

entitled "Decontamination of Drilling Rigs and Monitoring Well Materials." A detailed discussion of well development is provided in Driscoll, 1986.

Well development shall not be initiated until a minimum of 24 hours has elapsed subsequent to well completion. This time period will allow the cement grout to set. Wells typically are developed using bailers, low-yield pumping, or surging with a surge block or air. The appropriate method shall be specified in the project plans.

In general, all wells shall be developed until well water runs relatively clear of fine-grained materials. Typical limits placed on well development may include any one of the following:

- Clarity of water based on visual determination.
- A minimum pumping time period (typically one hour for shallow wells 10 to 30 feet deep).
- A minimum borehole volume (typically three borehole volumes) or until well goes dry.
- Stability of specific conductance, turbidity, and temperature measurements (typically less than 10 percent change between three successive measurements).

In addition, a volume equal to any water added during drilling will be removed above and beyond the requirement specified above.

Well development limits shall be specified in project-specific plans. A record of the well development (Figure A-3 in Attachment A) also shall be completed to document the development process.

Usually, a minimum period of one week should elapse between the end of initial development and the first sampling event for a well. This equilibration period allows groundwater unaffected by the installation of the well to occupy the vicinity of the screened interval. However, this stabilization period may be adjusted based upon project-specific requirements.

## **5.5 Contaminated Materials Handling**

SOP F504, entitled "Handling of Site Investigation Derived Waste," discusses the procedures to be used for the handling of auger cuttings, decontamination water, steam pad water, and development and purge water. Specific handling procedures should be delineated in the Sampling and Analysis Plan. In general, all site investigation generated wastes shall be containerized unless otherwise specified by the Sampling and Analysis Plan. The disposition of these wastes shall be determined after receipt of the appropriate analytical results.

## **5.6 Well Construction Records**

Field Well Construction Records shall be completed by the Drilling Inspector for each monitoring well installed. These records preferably shall be completed as the well is being constructed. However, due to space limitations on this form it may be more practical to record well installation information in the field logbook and later transfer it to the Field Well Construction Record. If well construction information is recorded in the field logbook, it must be transferred to the appropriate form within 5 days, and prior to demobilization from the field.

Field Well Construction Records (in Attachment C), shall include not only well construction information, but also information pertaining to the amount of materials used for construction. Some of the following items shall be recorded on the Field Well Construction Record, or in the field logbook, as appropriate:

- Project name and location.
- Project and Task number.
- Date and weather.
- Well identification designation.
- Drilling company and driller.
- Top of casing elevation (information collected after the site survey).
- Pay items including amount of screen and riser pipe used, amounts of cement, bentonite and sand used, and other well construction items.
- Well casing and borehole diameters.
- Elevations of (or depth to) top of steel casing, bottom of well, top of filter pack, top of bentonite seal, top of screen.

The information on the Field Well Construction Record will be used to generate a final Well Construction Record which combines the Field Boring and Well Construction Logs into one package. An example of all three documents is presented in Attachment C.

## **6.0 QUALITY ASSURANCE RECORDS**

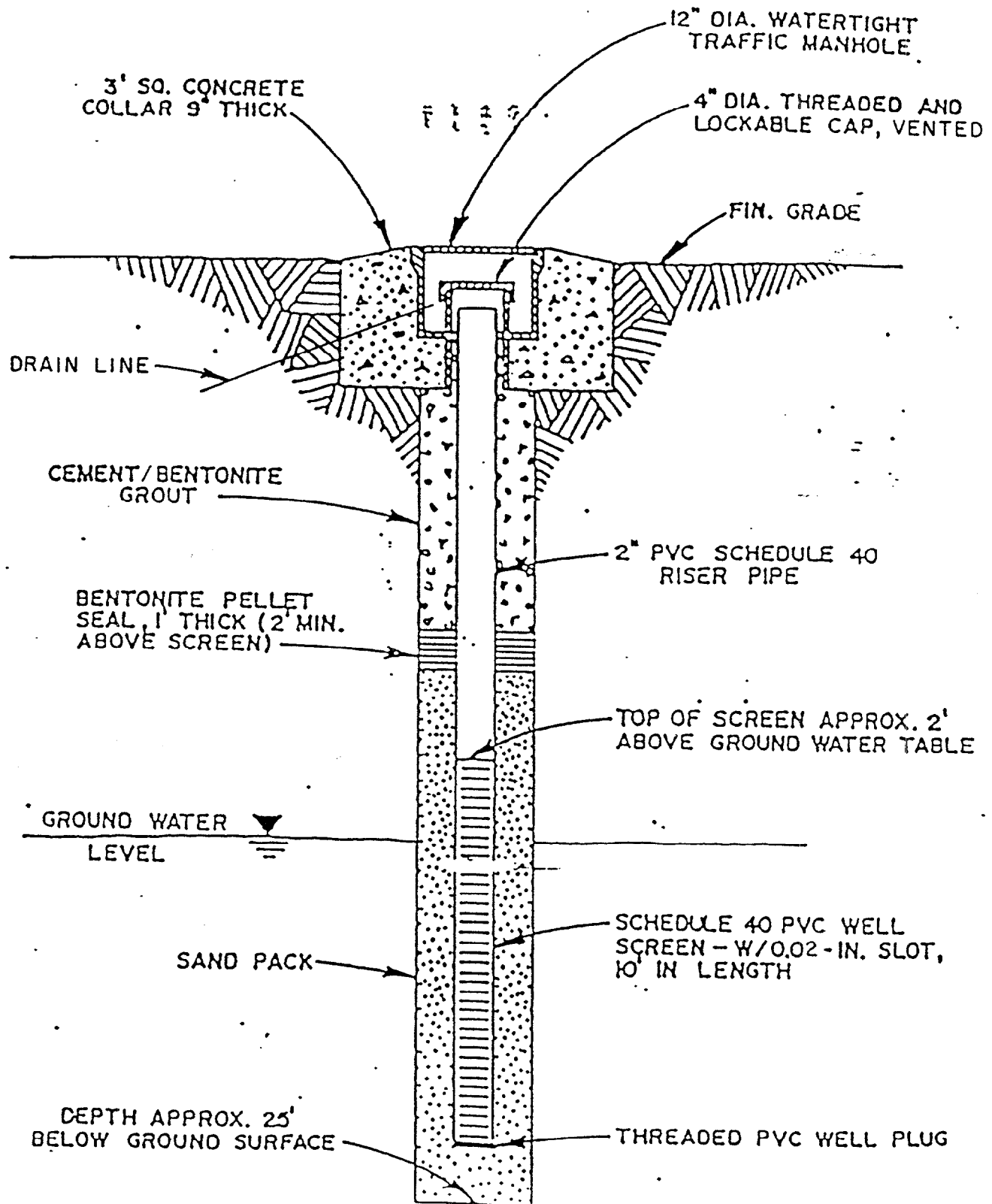
The Field Well Construction Record is the principle quality assurance record generated from well installation activities. Additionally, a Field Well Development Record shall also be completed, as well as pertinent comments in the field logbook.

## 7.0 REFERENCES

1. Driscoll, Fletcher, G., 1986, Groundwater and Wells, Johnson division. St. Paul, Minnesota. 2nd ed..
2. Roscoe Moss Company, 1990, Handbook of Ground Water Development. John Wiley & Sons. New York.
3. USEPA, September, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document.
4. Aller, L. et al. , June 1989, Handbook of Suggested Practices for the Design and Installation of Ground Water Monitoring Wells. National Water Well Association. Dublin, Ohio.

**ATTACHMENT A**  
**MONITORING WELL CONSTRUCTION**

Figure A-1

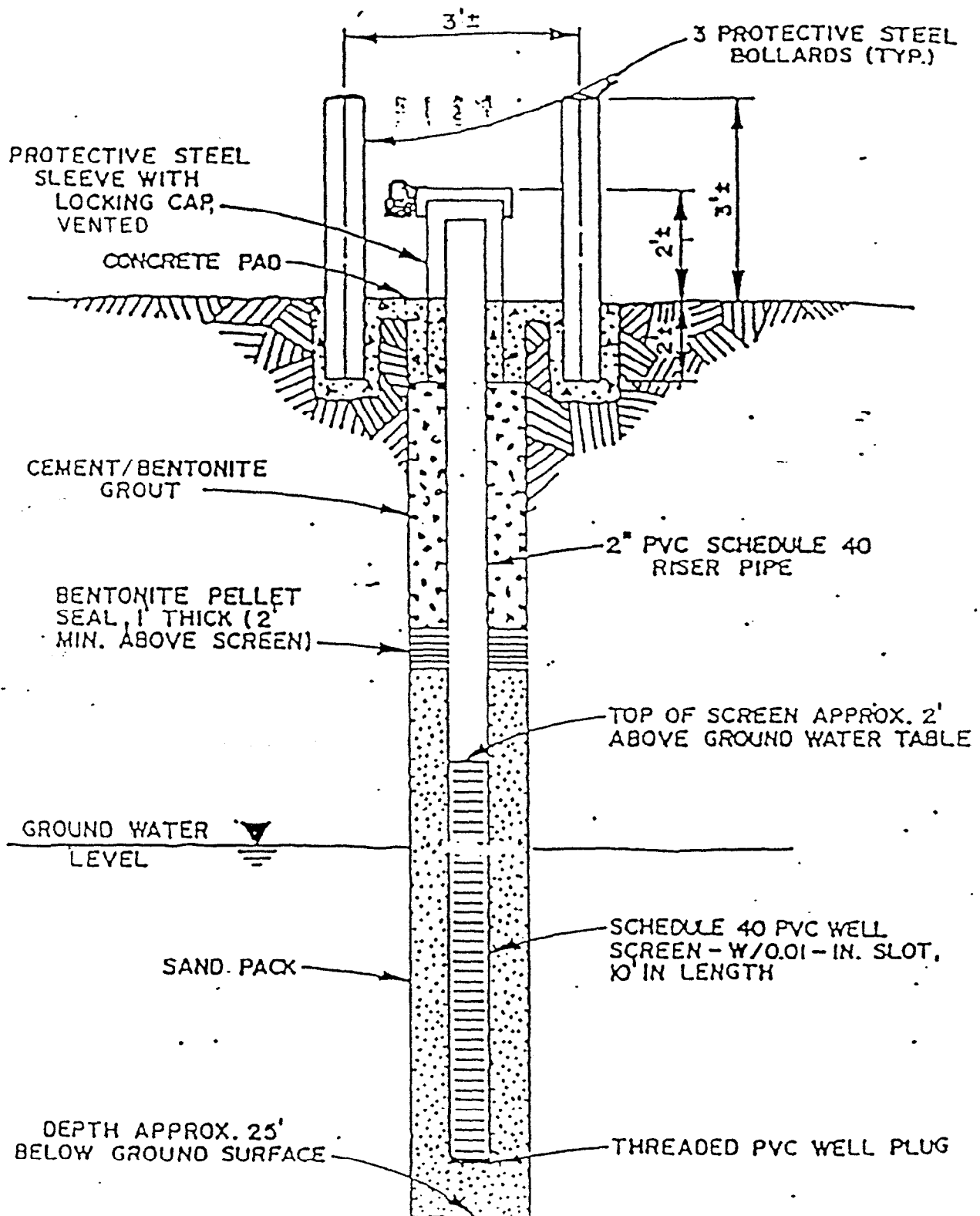


# MONITORING WELL CONSTRUCTION DETAIL (TRAFFIC AREA)

NOT TO SCALE



Figure A-2



# MONITORING WELL CONSTRUCTION DETAIL (NON TRAFFIC AREA)

NOT TO SCALE

**FIGURE A.3  
FIELD WELL DEVELOPMENT RECORD**

**Baker**

Baker Environmental, Inc

PROJECT: \_\_\_\_\_

CTO NO.: \_\_\_\_\_ WELL NO.: \_\_\_\_\_

DATE: \_\_\_\_\_

GEOLOGIST/ENGINEER: \_\_\_\_\_

TIME START	DEVELOPMENT DATA						
	TIME	CUMULATIVE VOLUME (gallons)	pH	TEMP (°C)	SPEC. COND. (µmhos/cm)	TEMP (°C)	COLOR AND TURBIDITY
TIME FINISH							
INITIAL WATER LEVEL (FT)							
TOTAL WELL DEPTH (TD)							
WELL DIAMETER (INCHES)							
CALCULATED WELL VOLUME							
BOREHOLE DIAMETER (INCHES)							
BOREHOLE VOLUME							
AMOUNT OF WATER ADDED DURING DRILLING							
DEVELOPMENT METHOD							
PUMP TYPE							
TOTAL TIME (A)							
AVERAGE FLOW (GPM)(B)							
TOTAL ESTIMATED WITHDRAWAL AxB=	OBSERVATIONS/NOTES						
HNU/OVA READING							

**ATTACHMENT B**

**ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

## **ATTACHMENT B**

### **ALTERNATE WELL CASING MATERIAL JUSTIFICATION**

The following is EPA's minimum seven point information requirements to justify the use of PVC as an alternate casing material for groundwater monitoring wells. If requested by EPA (USEPA Region IV), justification of the use of PVC should be developed by addressing each of the following items.

1. The Data Quality Objectives (DQOs) for the samples to be collected from wells with PVC casing as per EPA/540/G-87/003, "Data Quality Objectives for Remedial Response Activities."
2. The anticipated compounds and their concentration ranges.
3. The anticipated residence time of the sample in the well and the aquifer's productivity.
4. The reasons for not using other casing materials.
5. Literature on the adsorption characteristics of the compounds and elements of interest for the type of PVC to be used.
6. Whether the wall thickness of the PVC casing would require a larger annular space when compared to other well construction materials.
7. The type of PVC to be used and, if available, the manufacturers specifications, and an assurance that the PVC to be used does not leach, mask, react or otherwise interfere with the contaminants being monitored within the limits of the DQOs.

**ATTACHMENT C**

**FIELD TEST BORING RECORD AND  
FIELD WELL CONSTRUCTION RECORD FORMS**

**Baker**

Baker Environmental, Inc.

**TEST BORING AND WELL CONSTRUCTION RECORD**

PROJECT: \_\_\_\_\_  
 S.O. NO.: \_\_\_\_\_ BORING NO.: \_\_\_\_\_  
 COORDINATES: EAST: \_\_\_\_\_ NORTH: \_\_\_\_\_  
 ELEVATION: SURFACE: \_\_\_\_\_ TOP OF PVC CASING: \_\_\_\_\_

RIG:					DATE	PROGRESS (FT)	WEATHER	WATER DEPTH (FT)	TIME
	SPLIT SPOON	CASING	AUGERS	CORE BARREL					
SIZE (DIAM.)									
LENGTH									
TYPE									
HAMMER WT.									
FALL									
STICK UP									

REMARKS:

SAMPLE TYPE		WELL INFORMATION	DIAM	TYPE	TOP DEPTH (FT)	BOTTOM DEPTH (FT)
S = Split Spoon	A = Auger					
T = Shelby Tube	W = Wash					
R = Air Rotary	C = Core					
D = Denison	P = Piston					
N = No Sample						

Depth (Ft.)	Sample Type and No.	Samp. Rec. Ft. & %	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail			Elevation Ft. MSL
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Match to Sheet 2

DRILLING CO.: \_\_\_\_\_ BAKER REP.: \_\_\_\_\_  
 DRILLER: \_\_\_\_\_ BORING NO.: \_\_\_\_\_ SHEET 1 OF 2

**Baker**

Baker Environmental

**TEST BORING AND WELL CONSTRUCTION RECORD**

PROJECT: \_\_\_\_\_

S.O. NO.: \_\_\_\_\_

BORING NO.: \_\_\_\_\_

SAMPLE TYPE						DEFINITIONS		
S = Split Spoon    A = Auger T = Shelby Tube    W = Wash R = Air Rotary    C = Core D = Denison    P = Piston N = No Sample						SPT = Standard Penetration Test (ASTM D-1586) (Blows/0.5') RQD = Rock Quality Designation (%) Lab. Class. = USCS (ASTM D-2487) or AASHTO (ASTM D-3282) Lab. Moist. = Moisture Content (ASTM D-2216) Dry Weight Basis		
Depth (Ft.)	Sample Type and No.	Samp Rec. (Ft. & %)	SPT or RQD	Lab. Class. or Pen. Rate	PID (ppm)	Visual Description	Well Installation Detail	Elevation Ft. MSL
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								

DRILLING CO.: \_\_\_\_\_

DRILLER: \_\_\_\_\_

BAKER REP.: \_\_\_\_\_

BORING NO.: \_\_\_\_\_

SHEET 2 OF 2

**APPENDIX E**  
**WELL HEAD TESTING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
WELL-HEAD TESTING (SLUG-TESTS)**

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**Page 1 of 6  
SOP Number: F402  
Effective Date: 1993**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Overview
5.2	Applications
5.2.1	Static Measurement
5.2.2	Falling-Head Measurement
5.2.3	Rising-Head Measurement
5.3	Measurements and Measurement Intervals
5.4	Calculation Methods
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## WELL-HEAD TESTING (SLUG-TESTS)

### 1.0 PURPOSE

This SOP provides a general description of the technical methods and field procedures of a representative suite of well-head testing (slug tests) to approximate part of the aquifer parameters. The well-head tests are to be considered at all times as a reconnaissance of the aquifer parameters across an area (the site under investigation). Aquifer testing (pump-tests) to calculate these parameters is discussed in SOP F401. The descriptions herein are general in nature and do not apply to a specific well, well-field or project. Prior to designing well-head tests as part of a site investigation and during execution of the tests, the Project Manager, Site Manager and Program Hydrogeologist must consult on the appropriate procedures; these procedures must then be recorded in the project documents.

### 2.0 SCOPE

The well-head tests apply both to consolidated and unconsolidated strata; and to confined, semiconfined and phreatic conditions. The aquifer parameters subject to evaluation and approximate calculation are Transmissivity and Hydraulic Conductivity.

### 3.0 DEFINITIONS

The following definitions are extracted or abstracted from standard references (Section 7); further discussions are available in those references.

Hydraulic Conductivity (K) - A medium has a hydraulic conductivity (K) of unit length per unit time (for example, feet per day [ft/d]) if it will transmit in unit time a unit volume of groundwater at the prevailing viscosity through a cross-section of unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through unit length of flow (Lohman 1979).

Transmissivity (T) - The transmissivity (T) is the rate (for example, in gallons per day per foot of drawdown [gpd/ft]) at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient (Lohman 1979). The transmissivity is mathematically equivalent to the hydraulic conductivity multiplied by the saturated thickness:  $T = Kb$ .

Saturated Thickness (b) - The saturated thickness (b) is the distance (for example, in feet [ft]) from the elevation of the upper groundwater surface in either a phreatic system (the water table) or a confined or semiconfined system (the lower boundary of the upper confining or semiconfining layer, but not the potentiometric surface in a well) to the elevation of the upper boundary of the lower confining or semiconfining layer for the aquifer or water-bearing layer.

Drawdown (s) - The drawdown in a well affected by a well-head test is the differential distance, usually in feet (ft), between the static (unstressed) water level in the well measured immediately prior to the test, and the (stressed) water level at the specified time during the test.

Falling-Head Test - The falling-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically upward at the initiation of the test; the decay of this artificially impressed head is measured against time to provide data for the calculation of conductivity or transmissivity. The falling head test is valid only when the screen is fully submerged at static conditions.

Rising-Head Test - The rising-head test is conducted where the static water level in the subject well is nearly instantaneously displaced vertically downward at the initiation of the test; the decay of this artificially depressed head is measured against time to provide data for the calculation of conductivity or transmissivity.

Confined Conditions - Confined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are impermeable to water, and where the total head of the system at the upper surface of the groundwater is greater than atmospheric pressure. For a confined system, when a well is drilled below the bottom of the upper confining layer, the water level in the well rises to an elevation (at least) within or (possibly) above the upper confining layer.

Unconfined (Phreatic) Conditions - Unconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically only by a single surface or layer at the bottom of the water-bearing layer that is impermeable or semipermeable to water, and where the total head of the system at the upper surface of the groundwater is equal to atmospheric pressure. For an unconfined or phreatic or water-table system, when a well is drilled below the upper surface of the groundwater, the water level in the well does not rise to a significantly higher elevation.

Semiconfined Conditions - Semiconfined conditions in a water-bearing layer are found where the groundwater is bounded vertically by opposed surfaces or layers that are less permeable to water than the water-bearing layer itself, and where the total head of the system is greater than atmospheric pressure. For a semiconfined system, when a well is drilled below the bottom of the upper semiconfining layer, the water level in the well rises to an elevation within or above the upper semiconfining layer. However, one or both of the semiconfining layers will be, in some fashion, in hydraulic and hydrologic communication with the water-bearing layer, and may contribute water to or receive water from that layer.

#### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation procedures which deviate from those presented herein.

Site Manager - It is the responsibility of the Site Manager to ensure that the procedures herein are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Field Geologist - Responsible for determining the need for hydrogeologic testing and has overall responsibility for the planning and implementation of the test. Evaluation and interpretation of the data is also the responsibility of the Field Geologist.

Program Geologist - Responsible for QA/QC oversight of the planning and implementation of the test, along with the evaluation of data generated by the test.

## **5.0 PROCEDURES**

The procedures presented in this section concern the administration and execution of well-head tests; the technical content of a given test will be established by the project and program management for each instance according to experience and best professional practice.

### **5.1 Overview**

The well-head test will conform to the objectives of the investigation and to standards of good practice common in hydrogeologic investigations. Sufficient personnel, and sufficient standard and special equipment will be available for the intentions of the test. Data collection will conform to the practice described in SOP F202 (Water Level, Water/Product Level Measurements and Well Depth Measurements); additionally, time will be measured and recorded no less precisely than the nearest minute or half-minute, as appropriate, while conforming to the intent of the test. Containment and disposal of discharged liquids will conform to the practice described in SOP F504 (Handling of Site Investigation Wastes).

### **5.2 Applications**

The well-head test will usually be divided into three stages:

1. Static measurement
2. Falling-head test
3. Rising-head test

Each stage will normally be run for no more than 30 minutes. The water level in the test well should recover to between 90 and 100 percent of static conditions before beginning the next stage. Should the recovery be less than acceptable after 30 minutes from the start of the first stage, or should other field conditions conspire adversely, the second stage will not be run. Measurements of recovery during the first stage may then be extended to 60 minutes.

#### **5.2.1 Static Measurement**

This stage of the well-head test provides the data on static conditions to be used in subsequent approximation of the aquifer parameters. The static water levels are to be measured no later than immediately prior to the first stage of the test, whether falling-head or rising-head. The levels should also have been measured once daily, if possible, for two or more days preceding the test; the optimal measurement program would provide continuous measurement and recording of levels in all wells to be used for a period of several weeks preceding well-head testing.

### 5.2.2 Falling-Head Test

The falling-head stage of the well-head test is usually conducted before the rising-head. This stage imposes a stress on the water-bearing layer by nearly instantaneously injecting water or introducing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters. The falling head test is valid only when the screen is fully submerged at static conditions.

### 5.2.3 Rising-Head Test

The rising-head stage of the well-head test imposes a stress on the water-bearing layer by nearly instantaneously extracting water or removing a solid slug of impermeable material at one point (the test well). This is usually repeated at a large number of the available wells in the well-field. The measurements of the rate of recovery of the drawdown in the well provides data used in approximation of the aquifer parameters.

## 5.3 Measurements and Measurement Intervals

The measurement intervals for water levels in the test well during each stage will be modified from the following suggestions:

<u>Time Since Start of Test (min)</u>	<u>Measurement Frequency (min)</u>
0-5	0.5
5-10	1
10-20	2
20-60	5

The actual time and the test time for each reading will be recorded, with the water level measured to a precision of 0.01 ft.

The sequence of stations tested and the frequency of readings will be established by project and program management prior to the tests, and will be adjusted according to site conditions during the tests. The use of automatic data loggers is recommended due to the relatively fast recovery times of the small volume of water removed/introduced.

## 5.4 Calculation Methods

Calculation of the approximate values of the aquifer parameters will follow standard practice, with particular reference to the resources of Section 7, or as otherwise noted in the calculation sequence. A computer program, may also be used; if the computer program is used, an example that has previously been verified by traditional calculation will be run as part of the data from the subject site.

## 6.0 QUALITY ASSURANCE RECORDS

The readings made during the well-head test may be recorded in field books or on separate forms, according to management decisions. The field books will be stored according to SOP F303, with photocopies of the specific pages with test data included in the file for each test. The file for each test will include the field data, the calculations and graphs, and summaries with references for calculations by computer program.

## 7.0 REFERENCES

Chow, V.T. 1964. Handbook of Applied Hydrology. McGraw-Hill, New York.

Lohman, S.W. 1979. Ground-Water Hydraulics. Geological Survey Professional Paper 708. U.S. Government Printing Office.

Freeze, R.A. and Cherry, J.A. 1979. Groundwater. Prentice-Hall, Englewood Cliffs.

Driscoll, F.G., ed. 1986. Groundwater and Wells, 2nd ed. Johnson Filtration Systems, St. Paul.

Duffield, G.M., Rambaugh, J. O. 1989. AQTESOLV. Aquifer Test Solvert, Version 1.00 Documentation.

**APPENDIX F**  
**LOW FLOW PURGING AND SAMPLING**  
**PROCEDURES FOR GROUNDWATER SAMPLING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
LOW FLOW PURGING AND SAMPLING  
PROCEDURE FOR GROUNDWATER SAMPLING**

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**Page 1 of 11  
SOP Number: F106  
Effective Date: 04/94**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.4	Sampling
5.4.1	Equipment
5.4.2	Sampling Methods
5.4.3	Sample Containers
5.4.4	Preservation of Samples and Sample Volume Requirements
5.4.5	Handling and Transporting Samples
5.4.6	Sample Holding Times
5.4.7	Decontamination
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>



## **LOW FLOW PURGING AND SAMPLING PROCEDURE FOR GROUNDWATER SAMPLING**

### **1.0 PURPOSE**

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface utilizing low flow purging techniques.

### **2.0 SCOPE**

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard low flow purging and sampling techniques. The procedures described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

These procedures provide overall technical guidance for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates).

The Standard Operating Procedure (SOP) emphasizes the need to minimize aquifer stress by minimizing drawdown within the well, and low pumping rates (typically less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP best suited for monitoring wells that can accept a submersible pump and have a screened interval (or open length) of 10 feet or less. However, this procedure can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes. This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs).

The screened interval of the monitoring well should be located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screened interval.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown

in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

Ideally, the pump intake should be located between the upper third of the saturated screen length portion and the mid-point of the saturated screen length (which should not exceed 10 feet). However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (i.e., zones with higher permeability and/or greater chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Site-Specific Sampling and Analysis Plan or Workplan shall provide clear instructions on how the pump intake depth(s).

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 1 hour (or three well volumes, whichever is sooner) of purging, indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** – It is the responsibility of the Project Manager to ensure that field personnel responsible for sampling are familiar with these procedures. It also is the responsibility of the Project Manager to ensure that all appropriate documents (i.e., Purge records, COCs, etc.) have been completely and correctly filled out by the field team.

**Field Team Leader** – The Field Team Leader is responsible for the overall supervision of sampling activities. It also is the responsibility of the Field Team Leader to ensure that all field inspectors have been briefed on these procedures.

**Sampling Team Members** – The team members are responsible for the sampling of test pit and trenching activities. It is the Field Inspector's responsibility to log each test pit, document subsurface conditions, complete appropriate forms, and to direct the test pit or trenching activities.

## 5.0 PROCEDURES

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters. Specific methods shall be stated in the Field Sampling Plan (FSP) or Sampling and Analysis Plan (SAP).

### 5.4 Sampling

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used (See Section 5.4.1)
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, etc.

#### 5.4.1 **Equipment**

- 1) Extraction device- Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or Teflon). An adjustable rate, peristaltic pumps (suction) may also be used with caution, however, EPA guidance states, "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).

The use of inertial pumps is not recommended because these devices frequently cause greater disturbance during purging and sampling and generally are not as easily controlled as previously listed pumps. Increased disturbance can cause a higher degree of data variability.

- 2) Tubing- Teflon or Teflon lined polyethylene tubing are still preferred by USEPA in certain regions when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. A high grade PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

A small diameter tubing such as 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This smaller will help ensure the tubing remains liquid filled when operating at very low pumping rates. Pharmaceutical grade or food grade tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

- 3) Water level measuring device(s)- The water level should be graduated to 0.01 foot accuracy (electronic "tape", pressure transducer).
- 4) Flow measurement supplies- These can include a graduated cylinder, bucket, etc., and a stop watch).
- 5) Interface probe, if needed.
- 6) Power source- If a gasoline generator is used, it must be should be located downwind (i.e., recommended minimum of at least 30 feet from the well) so that the exhaust does not contaminate the samples.
- 7) Indicator field parameter monitoring instruments - as needed. Instruments typically used include the following meters-pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and thermometer. The use of a flow-through-cell is strongly recommended (required in some EPA regions) when measuring all of the listed parameters, except turbidity.

Standards solutions to perform field calibration of instruments are required. Analytical methods are for calibration are typically included in the SAP/QAPP or workplan (i.e., SOP). Additional references can be found in 40 CFR 136, 40 CFR 141, and SW-846.

- 8) Decontamination supplies- Decontamination procedures are typically listed in the SAP/QAPP or workplan (i.e., SOP). These include non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).
- 9) Logbook- Including other appropriate forms (i.e., well purging forms, sampling forms, etc.,).
- 10) Sample Bottles with sample tags or labels.
- 11) Sample preservation supplies.

- 12) Site-specific data- Well construction data, site map, previous field sampling data from last sampling event, if available.
- 13) Well keys or the location of well keys and name of the site contact.
- 14) Site specific Sample and Analysis Plan/Quality Assurance Project Plan and Workplan.
- 15) Health and Safety Monitoring Equipment- Including PID or FID instrument (if appropriate) to detect VOCs, Dreager tubes, Paticulate meters, etc,. The project HASP should be consulted to insure that the proper equipment is used in the field.

#### **5.4.2 Sampling Methods**

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNU or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.
2. Using decontaminated equipment (after proper respiratory protection has been donned), measure the total depth (to 0.1 ft.) and water level (to 0.01 ft.) with) and record these data in the field logbook. Care should be taken to minimize water column disturbance. All measurements must be taken from the established referenced point. If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date in the logbook.
3. Lay out sheet of clean polyethylene for monitoring and sampling equipment. Lower the pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well so that the pump intake is at the desired depth as designated in the workplan or SAP. After securing the safety cable, measure water level again before starting pump. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates that may be present in the bottom of the well.
4. Begin water removal. Start the pump at its lowest pump rate (i.e., speed) and then slowly increase the pumping rate until groundwater starts to discharge from the tubing. Check the water level in the well. Adjust the pumping rate until there is little or no water level drawdown (ideally less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameters stabilize. Collect the purged water and dispose of it in an acceptable manner.
5. Measure the rate of discharge frequently; approximately every three to five minutes (or as appropriate) during purging. Be sure to record any pumping rate adjustments (both time

each adjustment is made and the resulting flow rate). A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters. Record the method of discharge measurement.

Pumping rates should be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of the indicator parameters. Ideally adjustments should be made in the first fifteen minutes of pumping in order to help minimize purging time. During the initial stages of pumping, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the pump intake level. The final purge volume should be greater than the stabilized drawdown volume plus the extraction tubing volume.

Monitoring wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic). If the well is essentially dewatered during purging activities, then the well should be sampled as soon as the water level has recovered sufficiently to provide the necessary sample volume needed for all anticipated samples. During the recovery period the pump intake should not be moved. Samples may then be collected even though the indicator field parameters have not stabilized.

6. Record measurements of specific conductance, temperature, pH, and turbidity during purging every three to five minutes (or less frequently, if appropriate). All measurements, except turbidity, must be obtained using a flow- through-cell. Monitoring probes must be submerged in water at all times. Additional monitoring parameters may be specified in the workplan or SAP. Note: during the early phase of purging emphasis should be placed on minimizing drawdown and stabilizing the pumping stress, and recording those adjustments.
7. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Generally, stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:
  - pH ( $\pm 0.1$  unit)
  - Turbidity (10% for values greater than 1 NTU)
  - DO (10%), specific conductance (3%)
  - Temperature (3%)
  - ORP/Eh ( $\pm 10$  millivolts).
8. Add preservative to sample bottles, if required (see QAPP). Label, tag, and number the sample bottle(s).
9. Collect water samples. Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell. During purging and sampling, the pump

tubing should remain filled with water so as to minimize possible changes in water chemistry.

VOC samples should be collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

According to USEPA Region I protocols (1996), if the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Fill the remaining sample containers in order of decreasing volatility (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

According to USEPA Region I protocols (1996), if determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical

concentrations of total mobile contaminants in ground water for human health risk calculations.

10. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
11. Pack the samples for shipping (see QAPP). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see QAPP).
12. Decontaminate all equipment (See Section 5.4.7).

### **5.4.3 Sample Containers**

For most samples and analytical parameters, either glass or plastic containers are satisfactory. The QAPP describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in the QAPP.

### **5.4.4 Preservation of Samples and Sample Volume Requirements**

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. The QAPP describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in the QAPP.

### **5.4.5 Handling and Transporting Samples**

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged, and thus possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in the QAPP. Be sure to place a temperature blank in each cooler.

### **5.4.6 Sample Holding Times**

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in the QAPP.

### **5.4.7 Decontamination**

All sampling equipment must be decontaminated prior to use in the first well and following sampling of each subsequent well. Pumps are not to be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below (taken from USEPA Region I, 1996).

#### **Procedure 1**

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:



Flush the equipment/pump with potable water. Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically. Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically. Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped. Flush with distilled/deionized water. The final water rinse must not be recycled.

## **Procedure 2**

Steam clean the outside of the submersible pump. Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. (Note: additives or solutions should not be added to the steam cleaner.) Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically. Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

## **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project number; sample name/number and location; sample type and matrix; sample bottle type; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; well depth; static water level (including date and time); field chemistry; QA/QC data for field instruments; sampling method; pumping rates; drawdown; volume of water pumped prior to sampling; weather conditions).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate, including any problems encountered should be highlighted. Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

## 7.0 REFERENCES

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

U. S. EPA, 1996. Low Stress (Low Flow) Purging and Sampling Procedure for the Collection of Ground Water Samples From Monitoring Wells, Revision 2. U. S. EPA Region I.

**APPENDIX G**  
**GROUNDWATER SAMPLE ACQUISITION**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
GROUNDWATER SAMPLE ACQUISITION**

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**Page 1 of 11  
SOP Number: F105  
Effective Date: 04/94**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Sampling, Monitoring, and Evaluation Equipment
5.2	Calculations of Well Volume
5.3	Evacuation of Static Water (Purging)
5.3.1	Evacuation Devices
5.4	Sampling
5.4.1	Sampling Methods
5.4.2	Sample Containers
5.4.3	Preservation of Samples and Sample Volume Requirements
5.4.4	Field Filtration
5.4.5	Handling and Transporting Samples
5.4.6	Sample Holding Times
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

**ATTACHMENT A -- ASTM D4448-85A STANDARD GUIDE FOR SAMPLING GROUNDWATER  
MONITORING WELLS**

**ATTACHMENT B -- ASTM D6001-96 STANDARD GUIDE FOR DIRECT PUSH WATER  
SAMPLING FOR GEOENVIRONMENTAL INVESTIGATIONS**

**ATTACHMENT C -- GROUNDWATER MONITORING GUIDANCE MANUAL,  
COMMONWEALTH OF PENNSYLVANIA, DEPARTMENT OF  
ENVIRONMENTAL PROTECTION, ACT 2, FEBRUARY 29, 1996**

## **GROUNDWATER SAMPLE ACQUISITION**

### **1.0 PURPOSE**

The purpose of this guideline is to provide general reference information on the sampling of groundwater wells. The methods and equipment described are for the collection of water samples from the saturated zone of the subsurface.

### **2.0 SCOPE**

This guideline provides information on proper sampling equipment and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described should be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methods.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the specific groundwater sampling techniques and equipment to be used, and documenting these in accordance with the Sampling and Analysis Plan. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader and the Project Manager. The sampling personnel are responsible for the proper acquisition of groundwater samples.

### **5.0 PROCEDURES**

To be useful and accurate, a groundwater sample must be representative of the particular zone being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of testing in order to minimize any changes in water quality parameters.

The groundwater sampling program should be developed with reference to ASTM D4448-85A, Standard Guide for Sampling Groundwater Monitoring Wells (Attachment A). This reference is not intended as a monitoring plan or procedure for a specific application, but rather is a review of methods. Specific methods

shall be stated in the Sampling and Analysis Plan (SAP). Also refer to Attachment B which is ASTM D6001-96, Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain largely isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach should be followed during sample withdrawal:

1. All monitoring wells shall be pumped or bailed prior to withdrawing a sample. Evacuation of three to five volumes is recommended for a representative sample.
2. Wells that can be pumped or bailed to dryness with the sampling equipment being used, shall be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of at least three well volumes of water is preferred; otherwise, a sample will be taken when enough water is available to fill the sample containers.

Stratification of contaminants may exist in the aquifer formation. This is from concentration gradients due to dispersion and diffusion processes in a homogeneous layer, and from separation of flow streams by physical division (for example, around clay lenses) or by contrasts in permeability (for example, between a layer of silty, fine sand and a layer of medium sand).

Purging rates and volumes for non-production wells during sampling development should be moderate; pumping rates for production wells should be maintained at the rate normal for that well. Excessive pumping can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column at that point, thus result in the collection of a non-representative sample. Water produced during purging shall be collected, stored or treated and discharged as allowed. Disposition of purge water is usually site-specific and must be addressed in the Sampling and Analysis Plan.

### **5.1 Sampling, Monitoring, and Evacuation Equipment**

Sample containers shall conform with EPA regulations for the appropriate contaminants and to the specific Quality Assurance Project Plan.

The following list is an example of the type of equipment that generally must be on hand when sampling groundwater wells:

1. Sample packaging and shipping equipment: Coolers for sample shipping and cooling, chemical preservatives, and appropriate packing cartons and filler, labels and chain-of-custody documents.

2. Field tools and instrumentation: PID; Thermometer; pH meter; turbidity meter; specific conductivity meter; appropriate keys (for locked wells) or bolt-cutter; tape measure; plastic sheeting; water-level indicator; calibrated buckets and, where applicable, flow meter.
3. Pumps
  - a. Shallow-well pumps: Centrifugal, Packer Pumps, pitcher, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing), as applicable.
  - b. Deep-well pumps: Submersible pump and electrical power generating unit, bladder pump with compressed air source, or air-lift apparatus, as applicable.
4. Tubing: Sample tubing such as teflon, polyethylene, polypropylene, or PVC. Tubing type shall be selected based on specific site requirements and must be chemically inert to the groundwater being sampled.
5. Other Sampling Equipment: Bailers, teflon-coated wire, stainless steel single strand wire, and polypropylene monofilament line (not acceptable in EPA Region I) with tripod-pulley assembly (if necessary).
6. Pails: Plastic, graduated.
7. Decontamination equipment and materials: discussed in SOP F501 and F502.

Ideally, sample withdrawal equipment should be completely inert, economical, easily cleaned, sterilized, and reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

## **5.2 Calculations of Well Volume for Purging**

To insure that the proper volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well pipe or casing. The volume can be easily calculated by the following method. Calculations shall be entered in the field logbook:

1. Obtain all available information on well construction (location, casing, screens, etc.).
2. Determine inside diameter of well or casing (D).
3. Measure and record static water level (DW-depth to water below ground level or top of casing reference point) to the nearest 0.01-foot, using one of the methods described in Section 5.1 of SOP F202.
4. Determine the depth of the well (TD) to the nearest 0.01-foot by sounding using a clean, decontaminated weighted tape measure, referenced to the top of PVC casing or ground surface.

5. Calculate the volume of water in the casing:

$$V_w = \frac{\pi D^2}{4} (TD - DW)$$

$$V_{gal} = V_w \times 7.48 \text{ gallons/ft}^3$$

Where:

$V_w$ =Volume of water standing in well in cubic feet (i.e., one well volume)

$\pi$  =pi, 3.14

D=Inside diameter of well, in feet

TD=Total depth of well in feet (below ground surface or top of casing)

DW=Depth to water in feet (below ground surface or top of casing)

6. Calculate the minimum number of gallons to be evacuated before sampling. (Note:  $V_{purge}$  should be rounded to the next highest whole gallon. For example, 7.2 gallons should be rounded to 8 gallons.)

$$V_{purge} = V_{gal} ( \# \text{ Well Vol} )$$

Where:

$V_{gal}$  =Volume of water in well in gallons  
 $V_{purge}$  = Volume of water to be purged from well in gallons  
 $\# \text{ Well Vol.}$  = Number of well volumes of water to be purged from the well (typically three to five)

Table 5-1 lists gallons and cubic feet of water per standing foot of water for a variety of well diameters.

**TABLE 5-1  
WELL VOLUMES**

Diameter of Casing or Hole (in.)	Gallons per Foot of Depth	Cubic Feet per Foot of Depth
1	0.041	0.0055
2	0.163	0.0218
4	0.653	0.0873
6	1.469	0.1963
8	2.611	0.3491
10	4.080	0.5454



### **5.3     Evacuation of Static Water (Purging)**

The amount of purging a well should receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer.

For defining a contaminant plume, a representative sample of only a small volume of the aquifer is required. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce significant groundwater flow from a wide area. Generally, three to five well volumes are considered effective for purging a well.

An alternative method of purging a well, and one accepted in EPA Regions I and IV, is to purge a well continuously (usually using a low volume, low flow pump) while monitoring specific conductance, pH, turbidity, and water temperature until the values stabilize. Values are considered to have stabilized when deviation is less than 10 percent of the mean. The well is considered properly purged when the values have stabilized.

If a well is dewatered before the required volume is purged, the sample should be collected from the well once as a sufficient volume of water has entered the well. In order to avoid stagnation, the well should not be allowed to fully recharge before the sample is collected. The field parameters (pH, conductance, and temperature) should be recorded when the well was dewatered.

The Project Manager shall define the objectives of the groundwater sampling program in the Sampling and Analysis Plan, and provide appropriate criteria and guidance to the sampling personnel on the proper methods and volumes of well purging.

#### **5.3.1    Evacuation Devices**

The following discussion is limited to those devices which are commonly used at hazardous waste sites. Note that all of these techniques involve equipment which is portable and readily available.

Bailers - Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line (e.g., Teflon-coated) is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Inexpensive.
- Minimal outgassing of volatile organics while the sample is in the bailer.
- Relatively easy to decontaminate and use.

Limitations on the use of bailers include the following:

- Limited volume of sample.
- Time consuming to remove stagnant water using a bailer.
- Collection and transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.
- Unable to collect depth-discrete sample.

Suction Pumps - There are many different types of inexpensive suction pumps including centrifugal, diaphragm, peristaltic, and pitcher pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump (generally not suitable for well purging) that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. The pitcher pump is a common farm hand-pump.

Advantages of suction pumps include:

- Few limitations with regards to well diameter
- Inexpensive
- Portable
- Readily available
- Tubing can be dedicated or easily decontaminated

Limitations on the use of suction pumps include the following:

- External power source
- Vacuum will cause loss of dissolved gas, including volatile organics
- Restricted to areas with water levels within 10 to 25 feet of the ground surface
- Internal components of the pumps may be difficult to decontaminate

Gas-Lift Samples - This group of samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Gas lift pumps are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation or loss of volatile organics. An inert gas such as nitrogen is generally used as a gas source.

Submersible Pumps - Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed air or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for two-inch diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- Potentially low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components is difficult and time-consuming.

#### **5.4     Sampling**

The sampling approach consisting of the following, should be developed as part of the Sampling and Analysis Plan prior to the field work:

1. Background and objectives of sampling.
2. Brief description of area and waste characterization.
3. Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
4. Sampling equipment to be used.
5. Intended number, sequence volumes, and types of samples. If the relative degrees of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these should be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
6. Sample preservation requirements.
7. Schedule.
8. List of team members.
9. Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

##### **5.4.1   Sampling Methods**

The collection of a groundwater sample includes the following steps:

1. First open the well cap and use volatile organic detection equipment (HNu or OVA) on the escaping gases at the well head to determine the need for respiratory protection. This task is usually performed by the Field Team Leader, Health and Safety Officer, or other designee.

2. When proper respiratory protection has been donned, measure the total depth and water level (with decontaminated equipment) and record these data in the field logbook. Calculate the fluid volume in the well according to Section 5.2 of this SOP.
3. Lower purging equipment or intake into the well to a distance just below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (e.g., DOT-approved 55-gallon drum).
4. Measure the rate of discharge frequently. A bucket and stopwatch are most commonly used; other techniques include using pipe trajectory methods, weir boxes or flow meters. Record the method of discharge measurement.
5. Observe peristaltic pump intake for degassing "bubbles" and all pump discharge lines. If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics. The preferred method for collecting volatile organic samples and the accepted method by EPA Regions I through IV is with a bailer.
6. Purge a minimum of three to five well volumes before sampling. In low permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Allow the well to recharge as necessary, but preferably to 70 percent of the static water level, and then sample.
7. Record measurements of specific conductance, temperature, pH, and turbidity during purging to ensure that the groundwater level has stabilized. Generally, these measurements are made after the removal of three, four, and five well volumes.
8. If sampling using a pump, lower the pump intake to midscreen or the middle of the open section in uncased wells and collect the sample. If sampling with a bailer, lower the bailer to the sampling level before filling (this requires use of other than a "bucket-type" bailer). Purged water should be collected in a designated container and disposed of in an acceptable manner.
9. (For pump and packer assembly only). Lower assembly into well so that packer is positioned just above the screen or open section and inflate. Purge a volume equal to at least twice the screened interval or unscreened open section volume below the packer before sampling. Packers should always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
10. In the event that groundwater recovery time is very slow (e.g., 24 hours), sample collection can be delayed until the following day. However, it is preferred that such a well be bailed early in the morning so that sufficient volume of water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record in the logbook.
11. Add preservative if required (see SOP F301). Label, tag, and number the sample bottle(s).

12. Volatile organics septum vials (40 ml) should be completely filled to prevent volatilization and extreme caution should be exercised when filling a vial to avoid turbulence which could also produce volatilization. The sample should be carefully poured down the side of the vial to minimize turbulence. As a rule, it is best to gently pour the last few drops into the vial so that surface tension holds the water in a "convex meniscus." The cap is then applied and some overflow is lost, but air space in the bottle is eliminated. After capping, turn the bottle over and tap it to check for bubbles; if any are present, repeat the procedure. If the second attempt still produces air bubbles, note on Chain-of-Custody form and in field notebook and submit sample to the laboratory.

Fill the remaining sample containers in order of decreasing volatility (semi-volatiles next, then pesticides, PCBs, inorganics, etc.).

13. Replace the well cap. Make sure the well is readily identifiable as the source of the samples.
14. Pack the samples for shipping (see SOP F301). Attach custody seals to the shipping container. Make sure that Chain-of-Custody forms and Sample Analysis Request forms are properly filled out and enclosed or attached (see SOP F302).
15. Decontaminate all equipment.

#### **5.4.2 Sample Containers**

For most samples and analytical parameters, either glass or plastic containers are satisfactory. SOP F301 describes the required sampling containers for various analytes at various concentrations. Container requirements shall follow those given in USEPA Standard Operating Procedures and Quality Assurance Manual (USEPA, 1991) and SOP F301.

#### **5.4.3 Preservation of Samples and Sample Volume Requirements**

Sample preservation techniques and volume requirements depend on the type and concentration of the contaminant and on the type of analysis to be performed. SOP F301 describes the sample preservation and volume requirements for most of the chemicals that will be encountered during hazardous waste site investigations. Sample volume and preservation requirements shall follow those given in USEPA, 1991, and SOP F301.

#### **5.4.4 Field Filtration**

In general, preparation and preservation of water samples for dissolved inorganics involve some form of filtration. All samples will be filtered in the field the same day as collection. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) utilizing the pressure provided by the upstream pumping device for its operation.

Filtration and preservation are to occur in the field on the same day as collected with the sample aliquot passing through a dedicated disposable 0.45 micron filter. Samples for organic analyses shall never be filtered.

#### **5.4.5 Handling and Transporting Samples**

After collection, samples should be handled as little as possible. It is preferable to use self-contained "chemical" ice (e.g., "blue ice") to reduce the risk of contamination. If water ice is used, it should be double-bagged and steps taken to ensure that the melted ice does not cause sample containers to be submerged and, thus, possibly become cross-contaminated. All sample containers should be enclosed in plastic bags or cans to prevent cross-contamination. Samples should be secured in the ice chest to prevent movement of sample containers and possible breakage. Sample packing and transportation requirements are described in SOP F301.

#### **5.4.6 Sample Holding Times**

Holding times (i.e., allowed time between sample collection and analysis) for routine samples are given in USEPA, 1991, and SOP F301.

### **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each sample that is collected. The following information will be recorded in the Field Logbook:

- Sample identification (site name, location, project no.; sample name/number and location; sample type and matrix; time and date; sampler's identity).
- Sample source and source description.
- Field observations and measurements (appearance; volatile screening; field chemistry; sampling method; volume of water purged prior to sampling; number of well volumes purged).
- Sample disposition (preservatives added; lab sent to; date and time).
- Additional remarks, as appropriate.

Proper chain-of-custody procedures play a crucial role in data gathering. SOP F302 describes the requirements for correctly completing a chain-of-custody form. Chain-of-custody forms (and sample analysis request forms) are considered quality assurance records.

### **7.0 REFERENCES**

American Society of Testing and Materials. 1987. Standard Guide for Sampling Groundwater Monitoring Wells. Method D4448-85A, Annual Book of Standards, ASTM, Philadelphia, Pennsylvania.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA, Environmental Services Division, Athens, Georgia.

**ATTACHMENT A**

**ASTM D4448-85A  
STANDARD GUIDE FOR SAMPLING GROUNDWATER MONITORING WELLS**



## Standard Guide for Sampling Groundwater Monitoring Wells<sup>1</sup>

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (1, 2).<sup>2</sup> The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for  $\mu\text{g/L}$  (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (3) and an EPA document (4) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

### 3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-34 on Waste Disposal and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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<sup>2</sup> The boldface numbers in parentheses refer to a list of references at the end of this guide.



**TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program**

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/ Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H <sub>2</sub> SO <sub>4</sub> to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluoro-carbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluoro-carbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocar-bon-lined sep-tum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

#### 4. Well Flushing (Purging)

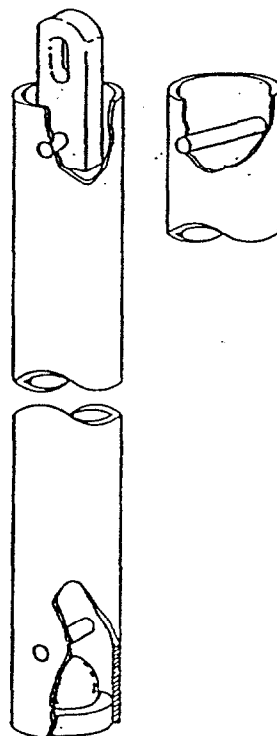
4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may

be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

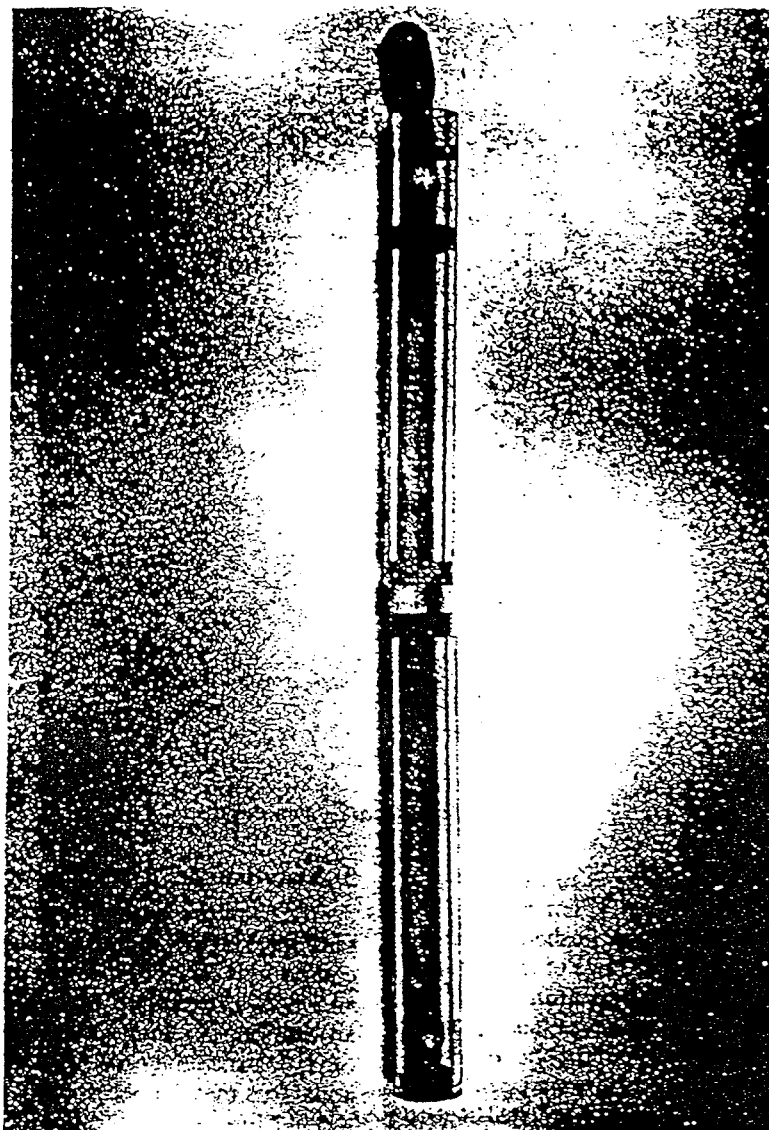
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

## 5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis ( $\mu\text{g/L}$  levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

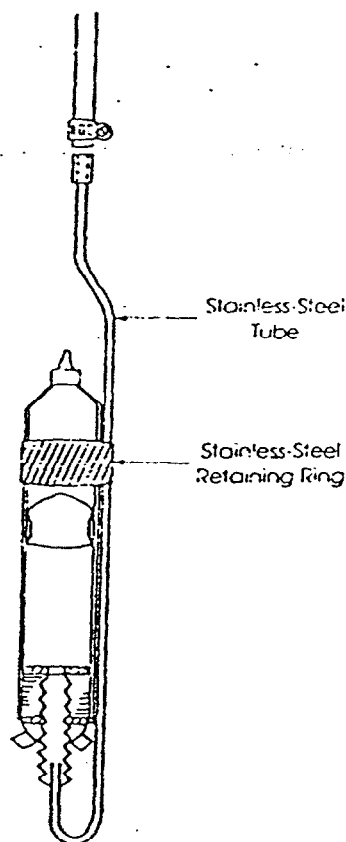
5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once

removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be non-plastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chem-

ical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluation (10, 12).

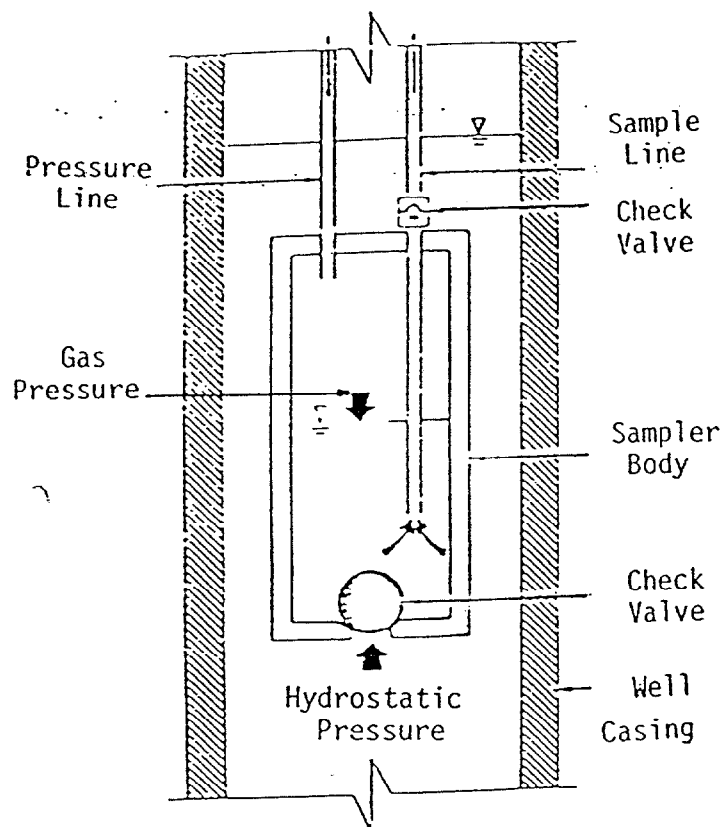
## 6. Sampling Equipment

6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screen wells and well clusters. The sampling devices can be categorized into the following eight basic types.

### 6.1.1 Down-Hole Collection Devices:

6.1.1.1 Bailers, messenger bailers, or thief samplers (10, 14) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. The devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling of volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposure surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in deep



NOTE—Taken from Ref (5).

FIG. 4 The Principal of Gas Displacement Pumping

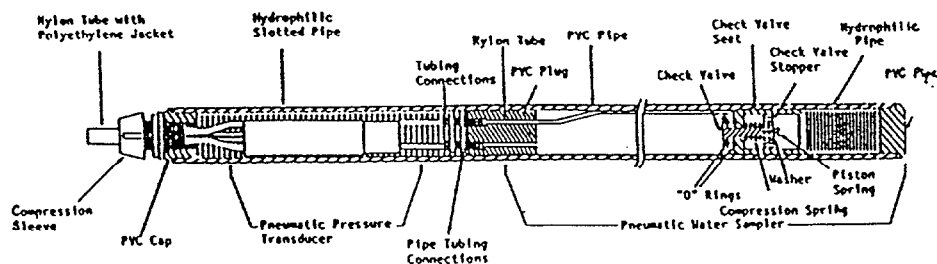
wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check

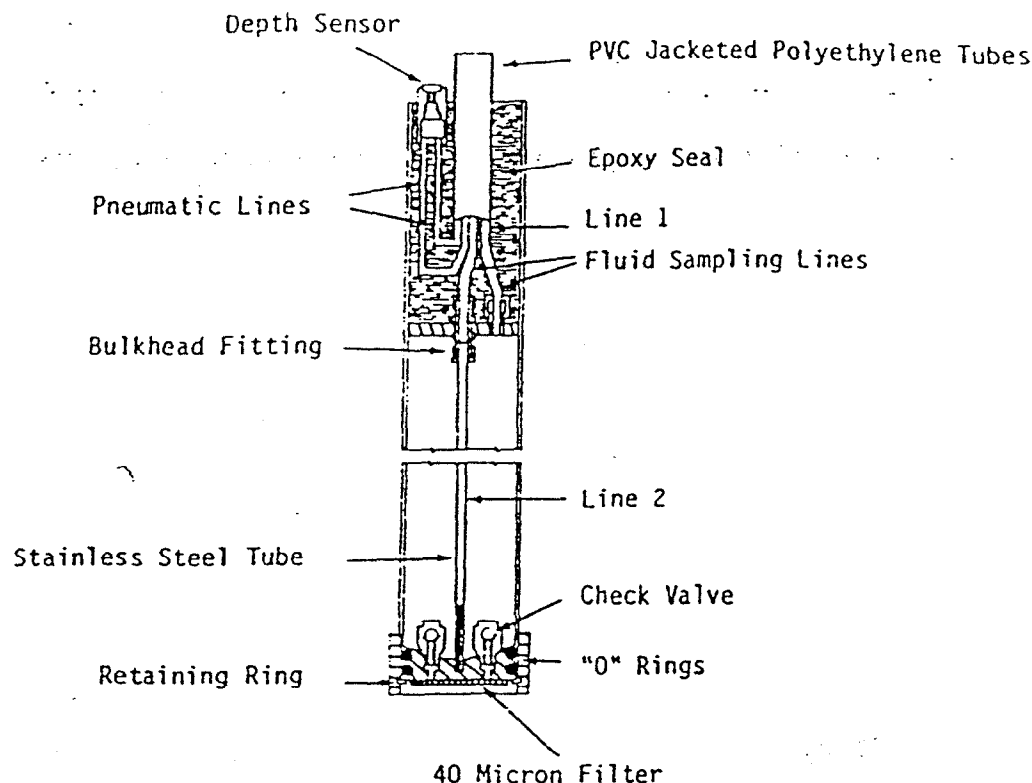
valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number

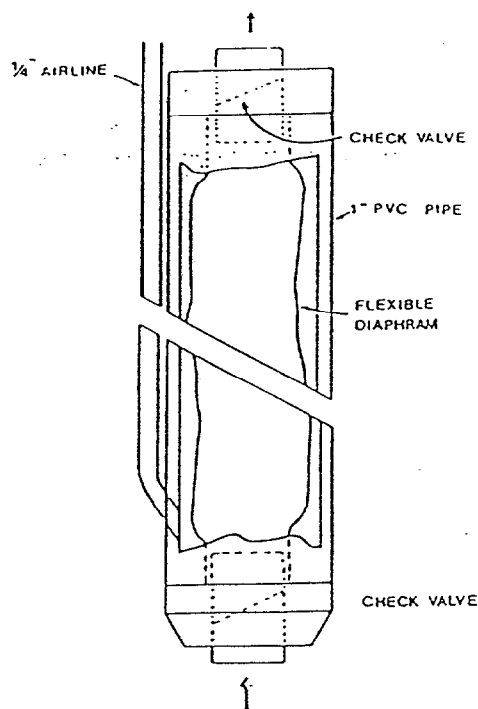
of thief or messenger devices are available in various materials and shapes.

#### 6.1.2 Suction Lift Pumps:

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton<sup>3</sup> for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or

mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

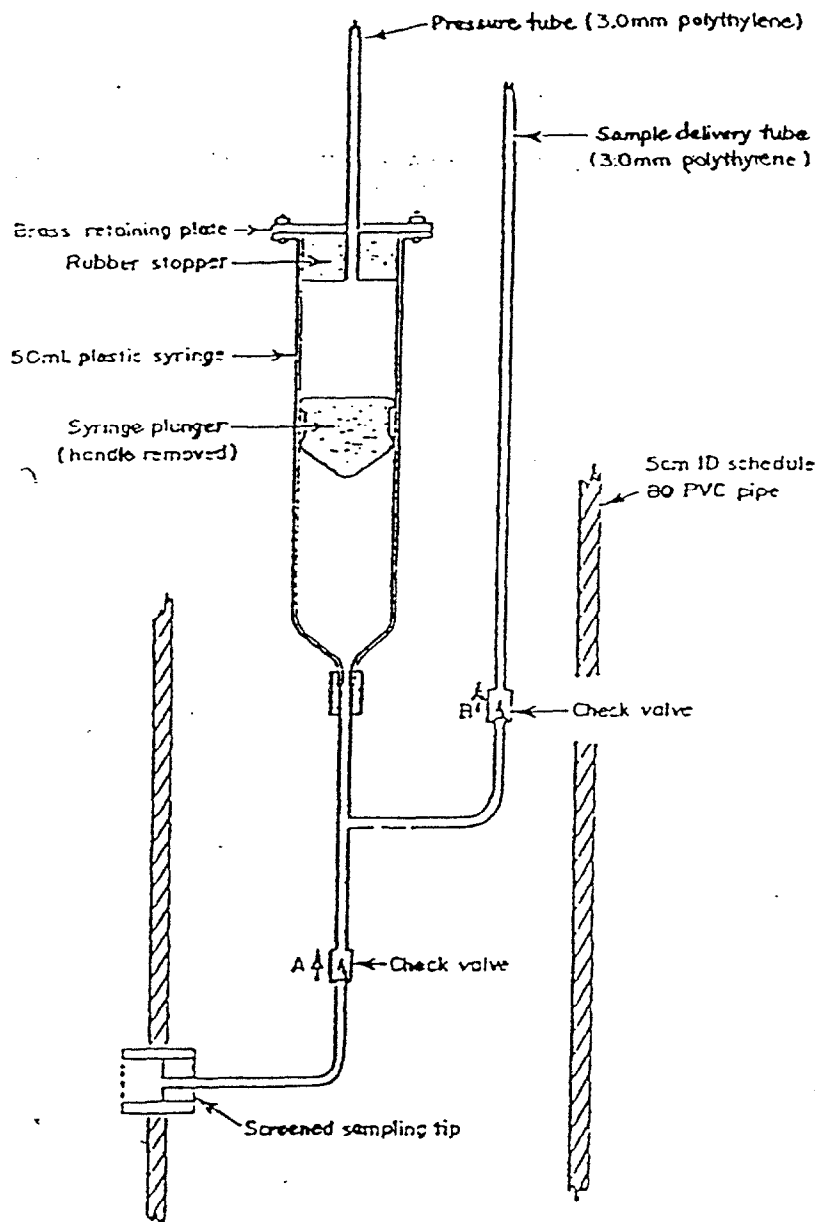
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE fluorocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

#### 6.1.3 Electric Submersible Pumps:

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

<sup>3</sup> Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

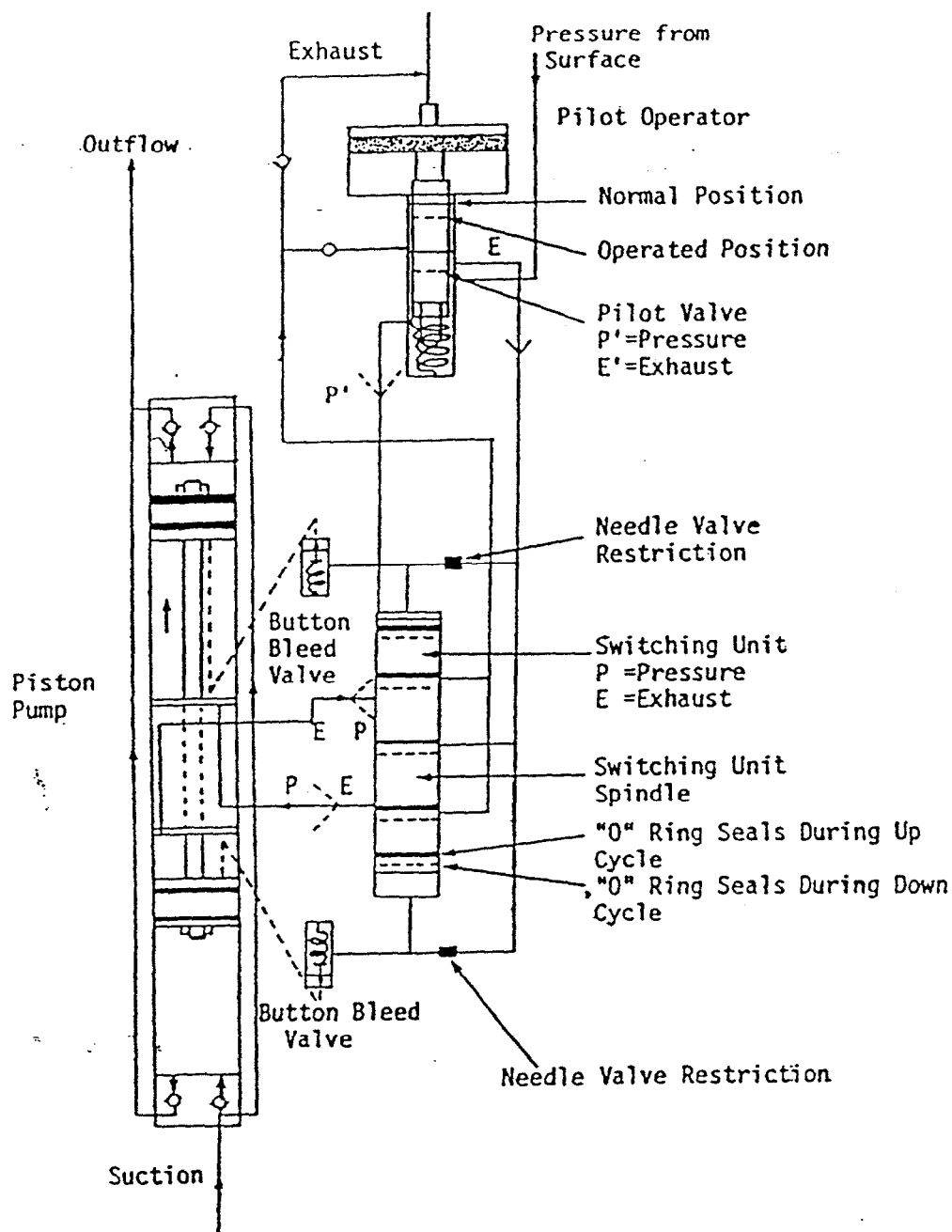
6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

#### 6.1.4 Gas-Lift Pumps:

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.





NOTE—Taken from Ref (49).

FIG. 9 Gas Driven Piston Pump

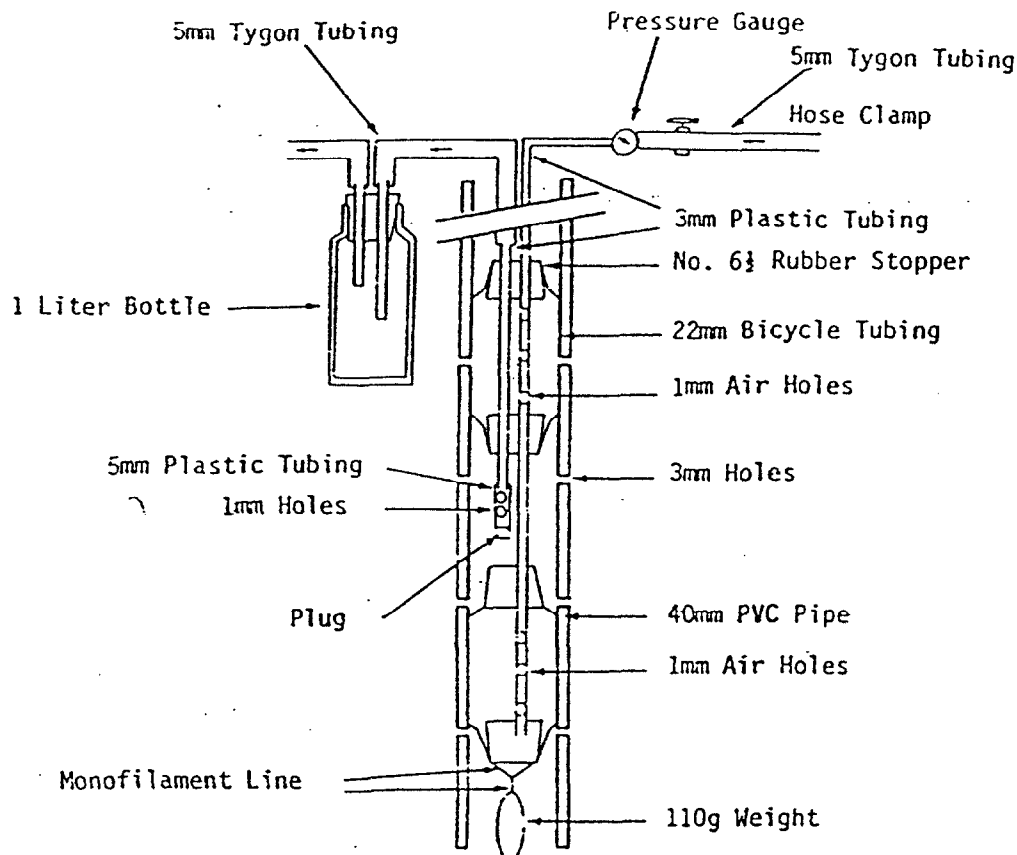
6.1.4.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, pressurized air bottles, and air compressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for volatile organics. The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (8) uncovered difficulties in sampling for inorganics. These difficulties were attributed to changes in redox, pH,

and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

#### 6.1.5 Gas Displacement Pumps:

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sampler in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

#### 6.1.6 Bladder Pumps:

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.<sup>3</sup> A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

#### 6.1.7 Gas Driven Piston Pumps:

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8 gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

#### 6.1.8 Packer Pump Arrangement:

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (48, 49, 50, 51). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (52).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

## 7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate

refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially pre-cleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (14, 53).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (13, 14, 50, 54, 55, 56). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (14). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and

pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other

parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45  $\mu\text{m}$  membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

## REFERENCES

- (1) Gibb, J. P., Schuller, R. M., Griffin, R. A., *Monitoring Well Sampling and Preservation Techniques*, EPA-600/9-80-101, 1980.
- (2) Pettyjohn, W. A., Dunlap, W. J., Cosby, R. L., Keeley, J. W., "Sampling Ground Water for Organic Contaminants," *Ground Water*, Vol 19, (2), March/April 1981, pp. 180-189.
- (3) Dunlap, W. J., McNabb, J. F., Scaff, M. R., Cosby, R. L., *Sampling for Organic Chemicals and Microorganisms in the Subsurface*, EPA-600/2-77-176, NTIS PB 276 679, August 1977, 35 pp.
- (4) Scaff, M. R., McNabb, J. F., Dunlap, W. J., and Cosby, R. L., *Manual of Ground Water Quality Sampling Procedures*, National Water Well Association, NTIS PB-82 103 045, 1981.
- (5) "A Guide to Groundwater Sampling," *NCASI Technical Bulletin*, No. 362, January 1982.
- (6) Humenick, M. J., Turk, L. J., Coldrin, M., "Methodology for Monitoring Ground Water at Uranium Solution Mines," *Ground Water*, Vol 18 (3), May-June 1980, p. 262.
- (7) Marsh, J. M., and Lloyd, J. W., "Details of Hydrochemical Variations in Flowing Wells," *Ground Water*, Volume 18 (4), July-August 1980, p. 366.
- (8) Gibb, J. P., Schuller, R. M., Griffin, R. A., "Collection of Representative Water Quality Data from Monitoring Wells," *Proceeding of the Municipal Solid Waste Resource Recovery Symposium*, EPA-600/9-81-002A, March 1981.
- (9) Boettner, E. A., Gwendolyn, L. B., Zand, H., Aquino, R., *Organic and Organotin Compounds Leached from PVC and CPVC Pipe*, NTIS P8 82-108 333, 1982.
- (10) Junk, G. A., Svec, H. J., Vick, R. D., Avery, M. J., "Contamination of Water by Synthetic Polymer Tubes," *Environmental Science and Technology*, Vol 8 (13) 1100, December 1974.
- (11) Louneman, W. A., Bufalini, J. J., Kuntz, R. L., and Meeks, S. A., "Contamination from Fluorocarbon Films," *Environmental Science and Technology*, Vol 15 (1), January 1981.
- (12) ASC Committee on Environmental Improvement, "Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry," *Analytical Chemistry*, Vol 52, 1980, pp. 2242-2249.
- (13) *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977.
- (14) *Handbook for Sampling and Sample Preservation of Water and Wastewater*, U.S. Dept. of Commerce NTIS PB-259 946, September 1976.
- (15) Timco Manufacturing Co., Inc., "Variable Capacity Bailer," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
- (16) deVera, E., Simmons, B., Stephens, R., Storm, D., *Samplers and Sampling Procedures for Hazardous Waste Streams*, Environmental Protection Agency, EPA-600/2-80-018, 1980, p. 51.
- (17) Morrison, R., *Ground Water Monitoring Technology*, Timco Manufacturing Co., 1982, p. 276.
- (18) Eijelkamp, "Equipment for Soil Research," *General Catalogue*, Geisbeek, The Netherlands, 1979, pp. 82-83.
- (19) Wood, W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, 1976, p. 24.
- (20) Gilham, R. W., "Syringe Devices for Groundwater Monitoring," *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982, p. 36.
- (21) Masterflex, *Masterflex Pump Catalogue*, Barnant Corp., Barrington, IL, 1981.
- (22) "Guidelines for Contracting Sampling and Analyses for Priority Pollutants in Pulp and Paper Industry Effluents," *NCASI Stream Improvement Technical Bulletin*, No. 335, August 1980.
- (23) Allison, L., "A Simple Device for Sampling Ground Water in Auger Holes," *Soil Science Society of America Proceedings* 35: 844-45, 1971.
- (24) Willardson, L., Meek, B., Huber, M., "A Flow Path Ground Water

- Sampler," *Soil Science Society of America Proceedings* 36: 965-66, 1972.
- (25) Wilson, L., *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, U.S. Environmental Protection Agency, EPA-600/17-80-134, 1980, p. 180.
  - (26) *Ground Water and Wells*, Johnson, E. E., Inc., St. Paul, MN, 1980, p. 440.
  - (27) Keck, W. G. and Associates, *New "Keck" Submersible Water Sampling Pump for Groundwater Monitoring*, Keck, W. G. and Associates, East Lansing, MI, 1981.
  - (28) McMillion, L., and Keeley, J. W., "Sampling Equipment for Ground-Water Investigation," *Ground Water*, Vol 6, 1968, pp. 9-11.
  - (29) Industrial and Environmental Analysts, Inc., *Procedures and Equipment for Groundwater Monitoring*, Industrial and Environmental Analysts, Inc., Essex Junction, VT, 1981.
  - (30) Trescott, P., and Pinder, G., "Air Pump for Small-Diameter Piezometers," *Ground Water*, Vol 8, 1970, pp. 10-15.
  - (31) Sommerfeldt, T., and Campbell, D., "A Pneumatic System to Pump Water From Piezometers," *Ground Water*, Vol 13, p. 293.
  - (32) Smith, A., "Water Sampling Made Easier with New Device," *The Johnson Drillers Journal*, July-August 1976, pp. 1-2.
  - (33) Morrison, R., and Ross, D., "Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites," *Proceedings of 1978 National Conference on Control of Hazardous Material Spills*, April 13, Miami Beach, FL, 1968, pp. 281-286.
  - (34) Morrison, R., and Brewer, P., "Air-Lift Samplers for Zone-of-Saturation Monitoring," *Ground Water Monitoring Review*, Spring 1981, pp. 52-54.
  - (35) Morrison, R., and Timmons, R., "Groundwater Monitoring II," *Groundwater Digest*, Vol 4, 1981, pp. 21-24.
  - (36) Bianchi, W. C., Johnson, C., Haskell, E., "A Positive Action Pump for Sampling Small Bore Holes," *Soil Science Society of America Proceedings*, Vol 26, 1961, pp. 86-87.
  - (37) Timmons, R., Discussion of "An All-Teflon Bailer and An Air-Driven Pump for Evacuating Small-Diameter Ground-Water Wells" by D. Buss and K. Bandt, *Ground Water*, Vol 19, 1981, pp. 666-667.
  - (38) Timco Manufacturing Co., Inc., "Gas Lift Teflon Pump," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.
  - (39) Tomson, M., King, K., Ward, C., "A Nitrogen Powered Continuous Delivery, All Glass Teflon Pumping System for Groundwater Sampling from Below 10 Meters," *Ground Water*, Vol 18, 1980, pp. 444-446.
  - (40) *Pneumatic Water Sampler*, Slope Indicator Co., Seattle, WA, 1982.
  - (41) Petur Instrument Co., Inc., *Petur Liquid Sampler*, Petur Instrument Co., Inc., Seattle, WA, 1982.
  - (42) Idler, G., "Modification of an Electronic Downhole Water Sampler," *Ground Water*, Vol 18, 1980, pp. 532-535.
  - (43) *Remote Sampler Model 200*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.
  - (44) Middleburg, R., "Methods for Sampling Small Diameter Wells for Chemical Quality Analysis," *Presented at the National Conference on Quality Assurance of Environmental Measurements*, Nov. 27-29, Denver, CO, 1978.
  - (45) *Air Squeeze Pump*, Leonard Mold and Die Works, Denver, CO, 1982.
  - (46) *Automatic Sampler Controller: Markland Model 105 and 2105*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 105/78, 1981.
  - (47) Gillham, R. W., and Johnson, P. E., "A Positive Displacement Ground-Water Sampling Device," *Ground Water Monitoring Review*, Vol 1 (2), Summer 1981, p. 33.
  - (48) Signor, D., "Gas-Driven Pump for Ground-Water Samples," *U.S. Geological Survey, Water Resources Investigation 78-72*, Open File Report, 1978.
  - (49) *Tigre Tierra HX Pneumatic Packer*, Tigre Tierra, Inc., Puyallup, WA, 1981.
  - (50) Cherry, R., "A Portable Sampler for Collecting Water Samples from Specific Zones in Uncased or Screened Wells," *U.S. Geological Survey*, Prof. Paper 25-C, 1965, pp. 214-216.
  - (51) Grisak, G., Merritt, W., Williams, D., "Fluoride Borehole Dilution Apparatus for Groundwater Velocity Measurements," *Canadian Geotechnical Journal*, Vol 14, 1977, pp. 554-561.
  - (52) Galgowski, C., Wright, W., "A Variable-Depth Ground-Water Sampler," *Soil Science Society of America Proceedings*, Vol 44, 1980, pp. 1120-1121.
  - (53) *Samplers and Sampling Procedures for Hazardous Waste Streams*, USEPA MERL Laboratory, Cincinnati, OH, EPA-600/2-80-018, January 1980.
  - (54) *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
  - (55) *Federal Register*, Vol 44, No. 244, Dec. 18, 1979, pp. 75050-75052.
  - (56) *Standard Methods for the Examination of Water and Wastewater*, APAA, 14th ed., Washington, DC, 1976, pp. 38-45.
  - (57) *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*, EPA-600/4-79-019, USEPA EMSL Laboratory, Cincinnati, OH, March 1979.
  - (58) U.S. Department of Interior, "Groundwater," Chapter II, *National Handbook of Recommended Methods for Water Data Acquisition*, 1980.

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**ATTACHMENT B**

**ASTM D6001-96  
STANDARD GUIDE FOR DIRECT PUSH WATER SAMPLING  
FOR GEOENVIRONMENTAL INVESTIGATIONS**



## Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations<sup>1</sup>

This standard is issued under the fixed designation D 6001; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

<sup>ε1</sup> NOTE—Paragraph 1.9 was added editorially October 1998.

### 1. Scope

1.1 This guide covers a review of methods for sampling ground water at discrete points or in increments by insertion of sampling devices by static force or impact without drilling and removal of cuttings. By directly pushing the sampler, the soil is displaced and helps to form an annular seal above the sampling zone. Direct-push water sampling can be one time, or multiple sampling events. Methods for obtaining water samples for water quality analysis and detection of contaminants are presented.

1.2 Direct-push methods of water sampling are used for ground-water quality studies. Water quality may vary at different depths below the surface depending on geohydrologic conditions. Incremental sampling or sampling at discrete depths is used to determine the distribution of contaminants and to more completely characterize geohydrologic environments. These investigations are frequently required in characterization of hazardous and toxic waste sites.

1.3 Direct-push methods can provide accurate information on the distribution of water quality if provisions are made to ensure that cross-contamination or linkage between water bearing strata are not made. Discrete point sampling with a sealed (protected) screen sampler, combined with on-site analysis of water samples, can provide the most accurate depiction of water quality conditions at the time of sampling. Direct-push water sampling with exposed-screen sampling devices may be useful and are considered as screening tools depending on precautions taken during testing. Exposed screen samplers may require development or purging depending on sampling and quality assurance plans. Results from direct-push investigations can be used to guide placement of permanent ground-water monitoring wells and direct remediation efforts. Multiple sampling events can be performed to depict conditions over time. Use of double tube tooling, where the outer push tube seals the hole, prevents the sampling tools from coming in contact with the formation, except at the sampling point.

1.4 Field test methods described in this guide include installation of temporary well points, and insertion of water samplers using a variety of insertion methods. Insertion methods include: (1) soil probing using combinations of impact, percussion, or vibratory driving with or without additions of smooth static force; (2) smooth static force from the surface using hydraulic penetrometer or drilling equipment, and incremental drilling combined with direct-push water sampling events. Under typical incremental drilling operations, samplers are advanced with assistance of drilling equipment by smooth hydraulic push, or mechanical impacts from hammers or other vibratory equipment. Methods for borehole abandonment by grouting are also addressed.

1.5 Direct-push water sampling is limited to soils that can be penetrated with available equipment. In strong soils damage may result during insertion of the sampler from rod bending or assembly buckling. Penetration may be limited, or damage to samplers or rods can occur in certain ground conditions, some of which are discussed in 4.6. Information in this procedure is limited to sampling of saturated soils in perched or saturated ground-water conditions.

1.6 This guide does not address installation of permanent water sampling systems such as those presented in Practice D 5092.

1.7 Direct-push water sampling for geoenvironmental exploration will often involve safety planning, administration, and documentation.

1.8 *This guide does not purport to address all aspects of exploration and site safety. It is the responsibility of the user of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations before its use.*

1.9 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many*

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground-Water and Vadose-Zone Investigations.

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unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>
  - D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)<sup>2</sup>
  - D 3441 Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil<sup>2</sup>
  - D 4448 Guide for Sampling Groundwater Monitoring Wells<sup>2</sup>
  - D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)<sup>2</sup>
  - D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites<sup>3</sup>
  - D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers<sup>3</sup>
  - D 5229 Practice for Decommissioning Monitoring Wells<sup>3</sup>
  - D 5254 Guide for Minimum Set of Data Elements to Identify a Ground Water Site<sup>3</sup>
  - D 5314 Guide for Soil Gas Sampling in the Vadose Zone<sup>3</sup>
  - D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock<sup>3</sup>
  - D 5474 Guide for Selection of Data Elements for Groundwater Investigation<sup>3</sup>
  - D 5521 Guide for Development of Ground Water Monitoring Wells in Granular Aquifers<sup>3</sup>
  - D 5778 Test Method for Performing Electronic Friction Cone and Piezocone Penetration Tests<sup>3</sup>
  - D 5730 Guide to Site Characterization for Environmental Purposes<sup>3</sup>
- ### 2.2 Drilling Methods:
- D 5781 Guide for the Use of Dual-Wall Reverse Circulation Drilling for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices<sup>3</sup>
  - D 5782 Guide for the Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices<sup>3</sup>
  - D 5783 Guide for the Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices<sup>3</sup>
  - D 5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices<sup>3</sup>
  - D 5786 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
  - D 5785 Guide for the Use of Cable Tool Drilling and Sampling Methods for Geoenvironmental Explorations

and Installation of Subsurface Water Quality Monitoring Devices

### 2.3 Soil Sampling:

- D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils<sup>2</sup>
- D 1587 Practice for Thin-Walled Tube Sampling of Soils<sup>2</sup>
- D 3550 Practice for Ring-Lined Barrel Sampling of Soils<sup>2</sup>
- D 4700 Guide for Soil Sampling in the Vadose Zone<sup>2</sup>

## 3. Terminology

3.1 Terminology used within this guide is in accordance with Terminology D 653 with the addition of the following:

3.2 Definitions in accordance with Practice D 5092.

3.3 *bailer*—a hollow tubular receptacle used to facilitate removal of fluid from a well or borehole.

3.4 *borehole*—a circular open or uncased subsurface hole created by drilling.

3.5 *casing*—pipe, finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, or to isolate the interval being monitored, or combination thereof.

3.6 *caving; sloughing*—the inflow of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength.

3.7 *centralizer*—a device that helps in the centering of a casing or riser within a borehole or another casing.

3.8 *jetting*—when applied as a drilling method, water is forced down through the drill rods or riser pipe and out through the end openings. The jetting water then transports the generated cuttings to the ground surface in the annulus of the drill rods or casing and the borehole. The term jetting may also refer to a well development technique.

3.9 *PTFE tape*—joint sealing tape composed of polytetrafluorethylene.

3.10 *well screen*—a filtering device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of uniform width, orientation, and spacing.

### 3.11 Definitions of Terms Specific to This Standard:

3.11.1 *assembly length*—length of sampler body and riser pipes.

3.11.2 *bentonite*—the common name for drilling fluid additives and well construction products consisting mostly of naturally occurring sodium montmorillonite. Some bentonite products have chemical additives that may affect water quality analyses (see 9.3.3).

3.11.3 *direct-push sampling*—sampling devices that are directly inserted into the soil to be sampled without drilling or borehole excavation.

3.11.4 *drill hole*—a cylindrical hole advanced into the subsurface by mechanical means; also, known as borehole or boring.

3.11.5 *effective screen length*—the length of a screen open or exposed to water bearing strata.

3.11.6 *effective seal length*—the length of soil above well screen that is in intimate contact with the riser pipe and prevents connection of the well screen with ground water from other zones.

3.11.7 *grab sampling*—the process of collecting a sample of

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

<sup>3</sup> Annual Book of ASTM Standards, Vol 04.09.



fluid exposed to atmospheric pressure through the riser pipe with bailers or other methods that may include pumping; also known as batch sampling.

3.11.8 *incremental drilling and sampling*—insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling is often needed to penetrate harder or deeper formations.

3.11.9 *in situ testing devices*—sensors or samplers, used for obtaining mechanical or chemical test data, that are typically pushed, rotated, or driven from the surface or below the bottom of a borehole following completion of an increment of drilling.

3.11.10 *intermittent sampling devices*—usually barrel-type samplers driven or pushed below the bottom of a borehole following completion of an increment of drilling.

3.11.11 *percussion driving*—insertion method where rapid hammer impacts are performed to insert the sampling device. The percussion is normally accompanied with application of static down force.

3.11.12 *push depth*—the depth below a ground surface datum that the end or tip of the direct-push water sampling device is inserted.

## 4. Summary of Guide

4.1 Direct-push water sampling consists of pushing a protected well screen to a known depth, opening the well screen over a known interval, and sampling water from the interval. A well point with an exposed screen can also be pushed with understanding of potential cross-contamination effects and purging requirements considered. A sampler with constant outside diameter is inserted directly into the soil by hydraulic jacking or hammering until sufficient riser pipe is seated into the soil to ensure a seal. Protected well screens can be exposed by retraction of riser pipes. While the riser is seated in the soil, water samples can be taken, and water injection or pressure measurements may be performed.

## 5. Significance and Use

5.1 Direct-push water sampling is an economical method for obtaining discrete ground-water samples without the expense of permanent monitoring well installation (1–4).<sup>4</sup> This guide can be used to profile potential ground-water contamination with depth by performing repetitive sampling events. Soils to be sampled must be permeable to allow filling of the sample in a relatively short time. The zone to be sampled can be isolated by matching well screen length to obtain discrete samples of thin aquifers. Use of these sampling techniques will result in more detailed site characterization of sites containing multiple aquifers. By inserting a protected sampling screen in direct contact with soil and with watertight risers, initial well development (Guide D 5521) and purging of wells may not be required for the first sampling event. Discrete water sampling, combined with knowledge of location and thickness of target aquifers, may better define conditions in thin multiple aquifers than monitoring wells with screened intervals that can intersect and allow for intercommunication of multiple aquifers

(2,4,5,7,8,11). Direct-push sampling performed without knowledge of the location and thickness of target aquifers can result in sampling of the wrong aquifer or penetration through confining beds.

5.2 For sites that allow surface push of the sampling device, discrete water sampling is often performed in conjunction with the cone penetration test (Test Method D 5778) (2–9), which is often used for stratigraphic mapping of aquifers, and to delineate high-permeability zones. In such cases, direct-push water sampling is normally performed close to cone holes. In complex alluvial environments, thin aquifers may vary in continuity such that water sampling devices may not intersect the same layer at equivalent depths as companion cone penetrometer holes.

5.3 Water sampling chambers may be sealed to maintain in situ pressures and to allow for pressure measurements and permeability testing (4,7,10). Sealing of samples under pressure may reduce the possible volatilization of some organic compounds. Field comparisons may be used to evaluate any systematic errors in sampling equipments and methods. Comparison studies may include the need for pressurizing samples, or the use of vacuum to extract fluids more rapidly from low hydraulic conductivity soils (8.1.5.3).

5.4 Degradation of water samples during handling and transport can be reduced if discrete water sampling events with protected screen samplers are combined with real time field analysis of potential contaminants. In limited studies, researchers have found that the combination of discrete protected screen sampling with onsite field analytical testing provide accurate data of aquifer water quality conditions at the time of testing (2,4). Direct-push water sampling with exposed screen sampling devices, which may require development or purging, are considered as screening tools depending on precautions that are taken during testing.

5.5 A well screen may be pushed into undisturbed soils at the base of a drill hole and backfilled to make permanent installed monitoring wells. Procedures to complete direct-push wells as permanent installations are similar to those given in Practice D 5092. These procedures allow for permanent sealing of riser pipe in the borehole. Some state or local regulations may not allow for certain types of direct-push installations as permanent monitoring wells depending on the application. Sometimes, where temporary well screens are inserted at the top of the ground water table, sealing an annulus may not be necessary.

5.6 In difficult driving conditions, penetrating to the required depth to ensure sealing of the sampler well screen may not be possible. If the well screen cannot be inserted into the soil with an adequate seal, the water-sampling event would require sealing in accordance with Practice D 5092 to isolate the required aquifer. Selection of the appropriate equipment and methods to reach required depth at the site of concern should be made in consultation with experienced operators or manufacturers. If there is no information as to the subsurface conditions, initial explorations consisting of penetration-resistance tests, such as Method D 1586, or actual direct-push testing trials can be performed to select the appropriate testing system.

<sup>4</sup> The boldface numbers in parentheses refer to a list of references at the end of this guide.

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5.6.1 Typical penetration depths for a specific equipment configuration depend on many variables. Some of the variables are the driving system, the diameter of the sampler and riser pipes, and the resistance of the materials.

5.6.2 Certain subsurface conditions may prevent sampler insertion. Penetration is not possible in hard rock and usually not possible in softer rocks such as claystones and shales. Coarse particles such as gravels, cobbles, and boulders may be difficult to penetrate or cause damage to the sampler or riser pipes. Cemented soil zones may be difficult to penetrate depending on the strength and thickness of the layers. If layers are present that prevent direct push from the surface, the rotary or percussion drilling methods (Guides D 5781, D 5782, D 5783, and D 5784, D 5785, D 5786, and see 2.2) can be employed to advance a boring through impeding layers to reach testing zones.

5.6.3 Driving systems are generally selected based on required testing depths and the materials to be penetrated. For systems using primarily static reaction force to insert the sampler, depth will be limited by the reaction weight of the equipment and penetration resistance of the material. The ability to pull back the rod string is also a consideration. Impact or percussion soil probing has an advantage of reducing the reaction weight required for penetration. Penetration capability in clays may be increased by reducing rod friction by enlarging tips or friction reducers. However, over reaming of the hole may increase the possibility of rod buckling and may allow for communication of differing ground-water tables. Hand-held equipment is generally used on very shallow investigations, typically less than 5-m depth, but depths on the order of  $10^1$  m have been reached in very soft lacustrine clays. Intermediate size driving systems, such as small truck-mounted hydraulic-powered push and impact drivers, typically work within depth ranges from 5 to 30 m, but can reach depths on the order of  $10^2$  m. Heavy static-push cone penetrometer vehicles, such as 20-ton trucks, typically work within depth ranges from 15 to 45 m, and also reach depth ranges on the order of  $10^2$  m in soft ground conditions. Drilling methods (Guides D 5781, D 5782, D 5783, D 5784, D 5785, D 5786, and also see 2.2) using drilling and incremental sampling are frequently used in all depth ranges and can be used to reach depths on the order of  $10^3$  m.

NOTE 1—Users and manufacturers cannot agree on depth ranges for different soil types. Users should consult with experienced producers and manufacturers to determine depth capability for their site conditions.

5.7 Combining multiple-sampling events in a single-sample chamber without decontamination (Practice D 5088) is generally unacceptable. In this application, purging of the chamber should be performed to ensure isolation of the sampling event. Purging should be performed by removing several volumes of fluid until new chemical properties have been stabilized or elements are flushed with fluid of known chemistry. Purging requirements may depend upon the materials used in the sampler and the sampler design.

## 6. Apparatus

6.1 *General*—A direct-push sampling system consists of a tip; well screen; chambers, if present; and riser pipes extending

to the surface. Direct-push water sampling equipment can be grouped into two classes, either with a sealed protected screen or exposed screen. Samplers with sealed screens depend on the seal to avoid exposure of the sampling interval to soil or water from other layers. They can be considered as accurate point-source detectors. They are normally decontaminated between sampling events. Exposed-screen samplers may require purging and development and as such are considered as screening devices for profiling relative degrees of contamination.

6.1.1 *Exposed-Screen Samplers*—Some direct-push samplers may consist of a simple exposed well screen and riser pipe that allows grab sampling with bailers or pumps. An example of this arrangement is the simple push or well point shown in Fig. 1. (12). The practice of jetting well points is often not acceptable due to the large quantities of water used

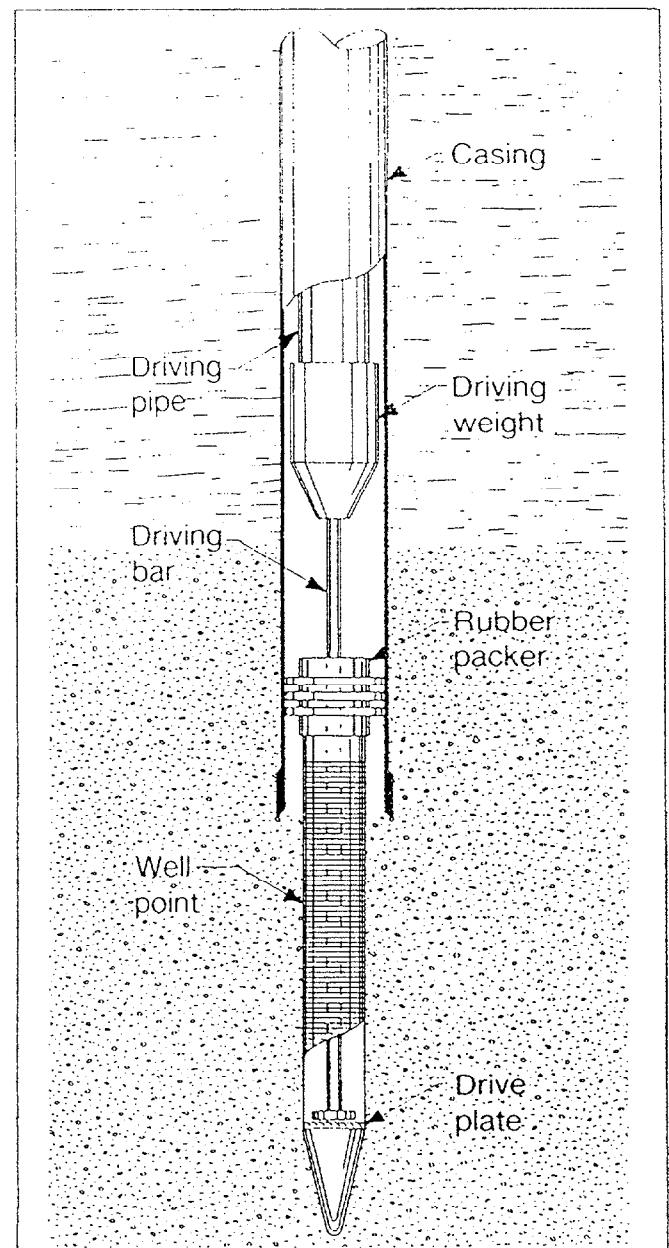


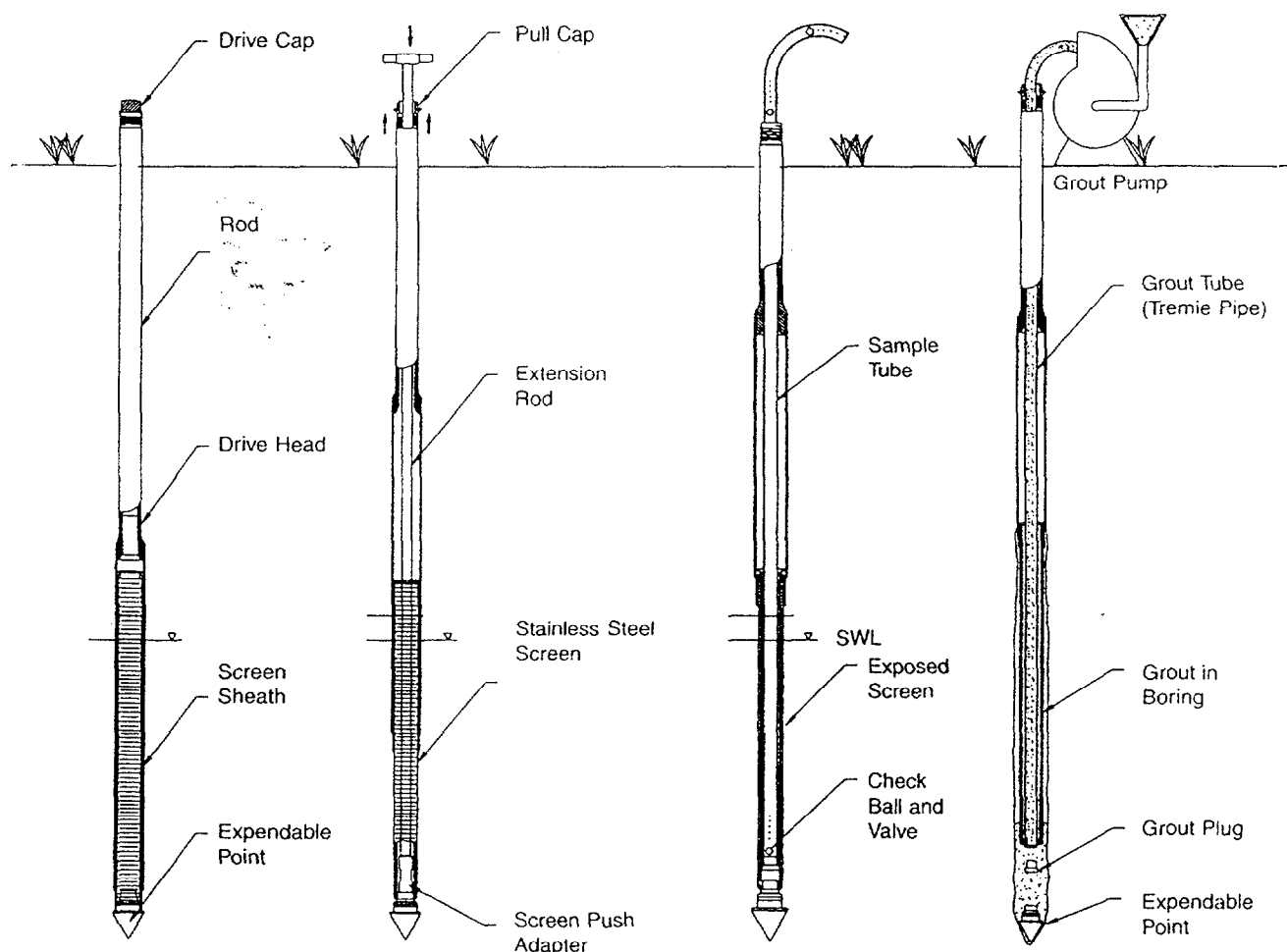
FIG. 1 Exposed-Screen Sampler—Well Point Driven Below the Base of a Borehole (12)

for insertion and the resulting potential for disturbance and dilution in the aquifer. If water is used for insertion, knowing the chemical constituents in the water may be necessary. Bias may be possible if an exposed-screen sampler is pushed through multiple contaminated layers. If exposed-screen well points are pushed through predrilled holes the screen and riser may fill with water present in the drill hole and require purging before sampling.

6.1.1.1 Another form of an exposed-screen sampler has been incorporated into cone penetrometer bodies (6). The cone penetrometers have sample chambers with measurement devices such as temperature and conductivity. Some cone penetrometers have been equipped with pumps for drawing in water samples into sample chambers or to the surface. Samplers equipped with chambers and subjected to multiple sampling events may require purging between sampling events. Although several of these designs have been proposed, they have not been successful in production practice. This is because of lengthy and time consuming purging requirements. In most cases, purging requirements and the depths of testing may be such that single-sampling events without cone pen-

etrometers may be more economical than multiple-sampling events requiring purging.

6.1.2 *Sealed-Screen Samplers*—Protected well screen and simple riser pipes for grab sampling are also deployed. An example is shown in Fig. 2 (13). This simple well screen arrangement allows for grab sampling through the riser pipe without purging or development if there is no leakage at the screen seals and riser pipes. Fig. 3 shows a schematic of a direct-push water sampler with a protected screen and with the ability to work in the grab sampling mode or by allowing water to enter a sample chamber in the sampler body (1). Most simple sample chambers allow for flow through the chamber. When flow through chambered samplers is opened, it is possible that the ground water from the test interval can fill into the rods above the chamber. In those cases, it may be advisable to add water of known chemistry into the rods prior to opening the screen. Some protected-screen samplers have sample chambers designed to reduce volume and pressure changes in the sample to avoid possible volatilization of volatile compounds (4,7,10). The need for pressurization is dependent on the requirements of the investigation program and should be



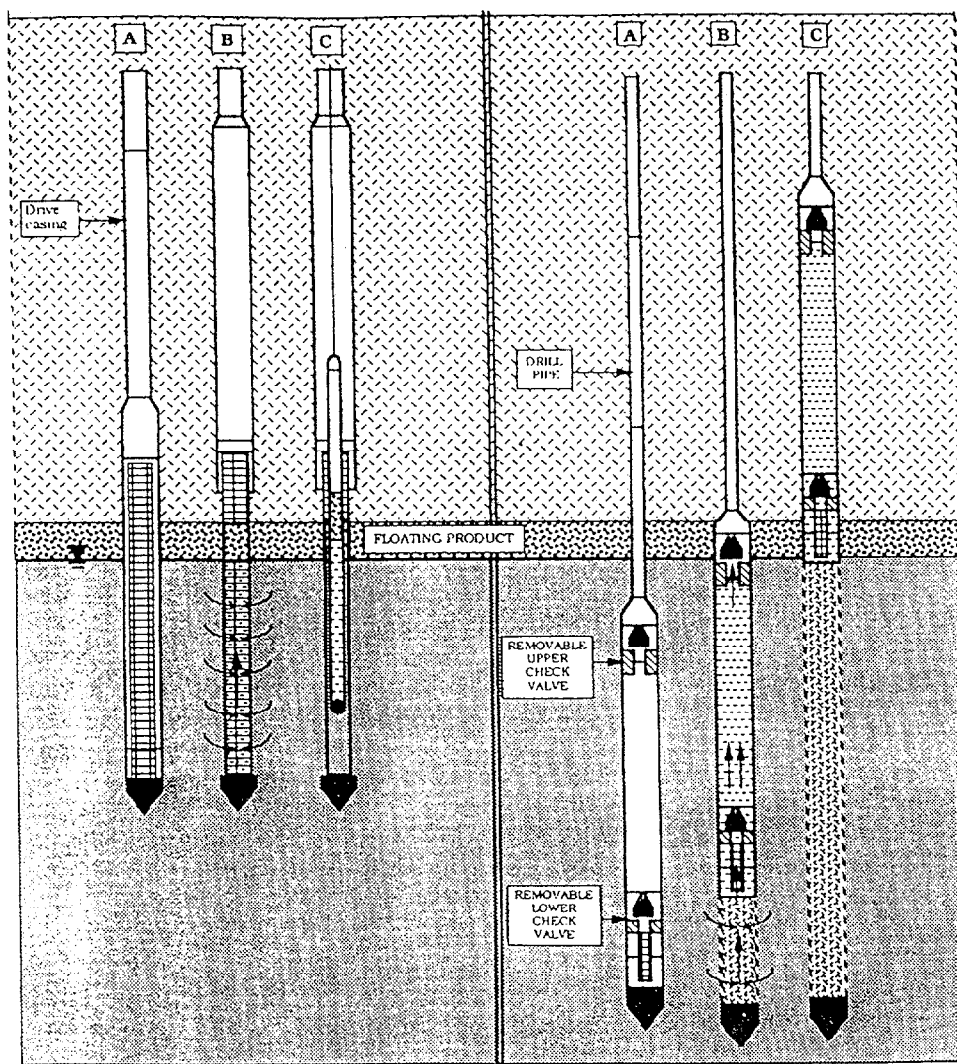
The assembled Sampler is driven to the desired sampling depth using standard rods.

Extension rods are used to hold the screen in position as the Casing Puller Assembly is used to retract the rods.

The tubing check valve can be used to sample groundwater.

Abandonment grouting can be conducted to meet ASTM requirements.

FIG. 2 Simple Protected Screen Sampler (13)



Legend: Grab Sampling

- A Penetrometer closed while being driven into position.  
 B Tool opened and 5 foot screen telescopes into position for collection of hydrocarbon or water sample at the very top of the aquifer.  
 C Hydrocarbon sample being collected using bailer lowered through drive casing.

Legend: Water Sampling in Chamber

- A Penetrometer closed while being driven into position.  
 B Cone separated and tool open to collect sample.  
 C Check valves closed as sample is retrieved within body of the tool.

FIG. 3 Protected Screen Sampler Capable of Working in Grab or Chamber Sampling Modes (1)

evaluated by comparison studies in the field with simpler systems allowing the sample to equalize at atmospheric pressure. There are different approaches to pressurizing the sample chamber including use of inert gas pressure or using sealed systems. An example of a sealed vial-septum system is shown in Fig. 4 (4). In the sealed vial system, a septum is punctured with a hypodermic needle connected to a sealed vial. With this approach the vial will contain both a liquid and gas at aquifer pressure. The sealed vial-septum system has been used in an exposed-screen mode.

**6.1.3 Materials of Manufacture**—The choice of materials used in the construction of direct-push water sampling devices should be based on the knowledge of the geochemical environment to be sampled and how the materials may interact with the sample by means of physical, chemical, or biological

processes. Due to the nature of insertion of these devices, the sampler body is typically comprised of steel, stainless steel, or metals of other alloys. The type of metal should be selected based on possible interaction effects with the fluid to be sampled. Well-screen materials can be selected from a variety of materials. Materials commonly used for well-screen elements include steel, stainless steel, rigid polyvinyl chloride (PVC), polytetrafluorethylene (PTFE), polyethylene (PE), polypropylene (PP), and brass. Sample chambers, pumps, and connector lines are also constructed with a variety of materials. Evaluating the possible interaction of materials that will be exposed to the water during the sampling event is important.

**6.2 Sampler Body**—The sampler body consists of a tip, and a barrel that consists of well screen, a protective sleeve if used, and a sampling chamber if used, with a connector assembly to

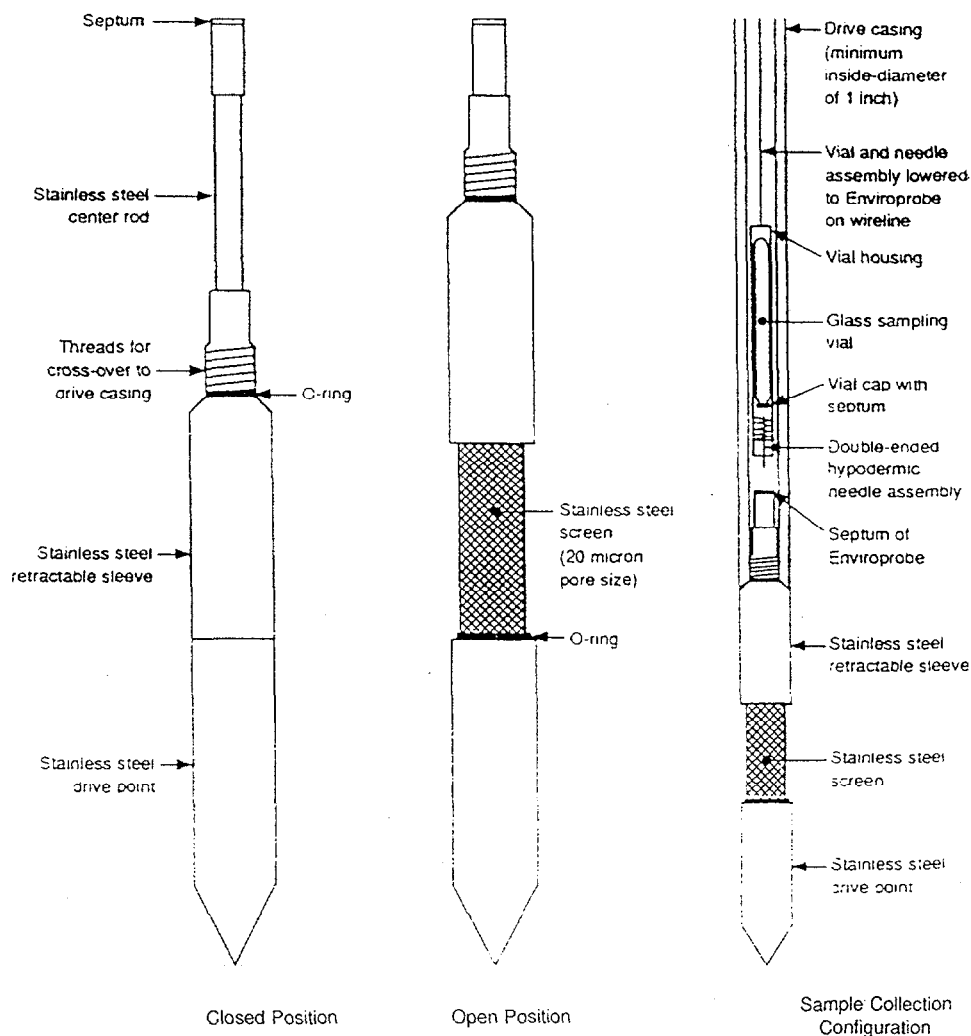


FIG. 4 Protected Screen Sampler with Sealed Vial System (4)

attach to riser pipes. The sampler is normally constructed of steel to withstand insertion forces. The sampler barrel should be of constant outside diameter to ensure intimate contact with the soil to be tested. Protective sleeves shall be equipped with O-rings to prevent the ingress of water before the sampling event.

**6.2.1 Expendable Sampler Tips**—Some sampler tips are expendable and are left in the ground after the sampling event. The tip should be equipped with an O-ring seal to the sampler sleeve to prevent leakage into the riser pipe until the sampling depth is reached.

**6.2.1.1 Sampler tips** are designed so that upon pull back of the sampler body and riser pipe, the tip is disconnected from the sampler. The required diameter, and the ability to expend the tip successfully, depends on the soils to be penetrated. The tip diameter can be set equal to, or slightly less than, the sampler body. If there are problems with tip retraction, tips can be designed with a diameter of 1 to 3 mm ( $\frac{1}{8}$  to  $\frac{1}{16}$  in.) larger than the sampler body. The use of an enlarged diameter with a larger shoulder or tip may help in reaching greater depths because it acts as a friction reducer. An enlarged tip should not leave too large an annulus above the sampler body and riser

pipes as to maintain a seal above the well screen and to prevent potential cross contamination.

**6.2.1.2 Most sampler tips** are made of steel to withstand pushing forces. With some samplers, after the sampling event, the tip may remain in the ground and the hole may be grouted. The user should consider if leaving the tips below the ground will adversely affect surrounding ground-water chemistry depending on site conditions.

**6.2.2 Well Screen**—Many materials for well screens are available for direct-push samplers. The material of manufacture should be selected with consideration of chemical composition of the ground water to be sampled and possible interactive effects (see 6.1.3). Some samplers use simple mill slotted steel, or PVC tube. Steel or brass screen formed into a cylinder can be used to cover inlets. Continuous-wrapped, wire-wound well points are also commonly used. The effective opening size of the well screen material should be selected based on the material to be sampled, the time required to sample, and soil sediment that can be tolerated in the water sample. Methods to size well-screen and filter-pack materials are given in Practice D 5092. Clean sands and gravels can be sampled with a screen with larger openings without producing

excessive sediment. Clayey and silty soils containing fines may require finer openings. Typical openings of 10 to 60  $\mu\text{m}$  are used. Finer openings will reduce sediment but may also slow ingress of fluid.

6.2.3 Some sampler inlets are not protected by well screen or slotting. The simplest form of sampler can be an open riser pipe with an expendable tip. The use of unprotected inlets has sometimes been useful to sample ground water at soil/bedrock interface. If unprotected inlets are used, one must consider the amount of soil sediment that can be tolerated in the sample.

6.3 *Riser Pipes*—Also commonly referred to as “push rods” or “extension rods”, riser pipes are normally constructed of steel to withstand pushing forces. Some temporary well-point installations may use a double-tube system such as a small-diameter PVC riser pushed by the steel tube (Fig. 5) (14). Double-tube systems are advantageous if multiple sampling events are required in a single push. Other temporary systems may use a flexible tubing system connected to the well point (Fig. 6) (14). For PVC riser pushed with outside steel tubing, the withdrawal of steel push rods will leave a small annulus between the soil and PVC riser or tubing. This annulus may require grouting depending on the effective seal above the well screen and the possibility of cross contamination of overlying layers. Cone penetrometer rods as specified in Test Method D 5778 are sometimes used in sampling systems deployed with

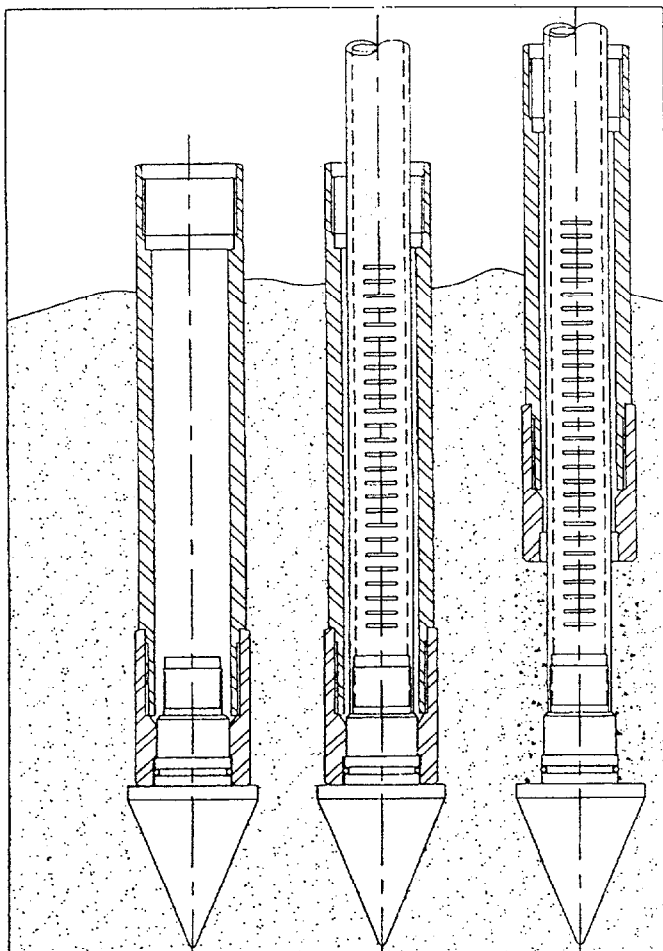


FIG. 5 Double-Tube Temporary Well Point System (14)

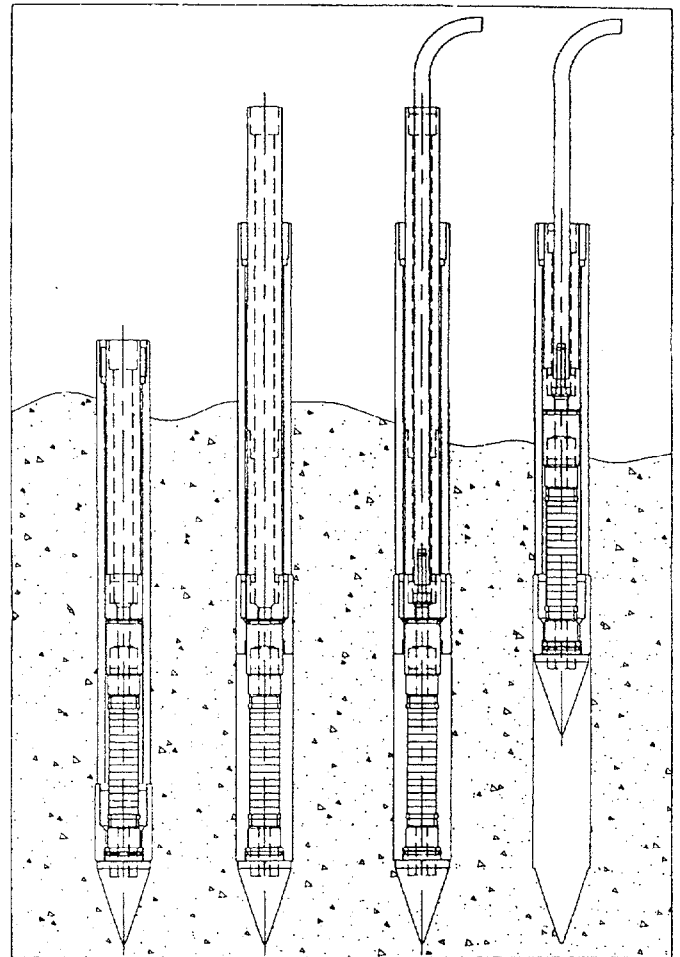


FIG. 6 Protected Screen Sampler with Sample Tubing (14)

cone penetrometer equipment. Larger diameter rods, typically 45 mm (1.75 in.), are sometimes used with cone penetrometer equipment. The maximum rod diameter that can be used depends on the material to be penetrated and the driving system. Increased rod diameter causes increase in the required driving force required to penetrate a sufficient distance. Most surface direct-push riser pipes are less than 50 mm (2 in.) in diameter.

6.4 Standard drilling rods used for rotary drilling are normally used when sampling is done at the base of drill holes. Many drill rods are available (see Guides D 5781, D 5782, D 5783, D 5784, D 5785, D 5786, and also see 2.2). For direct-push sampling systems that depend on the riser pipe for grab sampling within the riser, ensuring that joints are watertight will be necessary such that water enters through the well screen interval to be sampled. Rods should be wrench-tightened, and PTFE tape can be used on the threads to stop leakage. The quality checks discussed in Section 8 can be performed to evaluate possible leakage. Sometimes it may be necessary to equip rod joint shoulders with O-rings to prevent leakage. Cone penetrometer rods with precision tapered threads are normally watertight during short sampling events lasting up to 1 h if they are not damaged.

6.4.1 *Friction Reducers*—Friction reducers that have enlarged outside diameters of the riser pipe are sometimes

employed to reduce thrust capacity needed to advance the well point or sampler. If friction reducers are used, they must be a sufficient distance above the sampling location to ensure that fluids from overlying layers can enter the sampling zone. If cross-contamination is possible, use of friction reducers should be avoided. In some cases the use of friction reducers can help in forming an annular seal. Donut-type reducers ream the hole smoothly. Lug-type reducers rip and remold the soil and may provide a better annular seal. The type and location of friction reducers should be documented in the project report.

**6.4.2 Mud Injection**—Some direct-push systems inject bentonite drill fluid along the drill rods to reduce friction. These systems normally inject the fluid behind friction reducers. These systems may provide better sealing above the sampler for the sampling process but are also more difficult to operate.

**6.5 Sampling Devices**—Methods to obtain water samples vary widely. Examples are given in 6.1.1 and 6.1.2. Simple grab samplers, most often bailers, are used with simpler systems. Other systems draw water into chambers or sealed vials for retrieval to the surface. Some systems may have pumps and circulation systems to retrieve samples to the surface. The materials of manufacture of samplers, sample containers, pumps, and circulation lines should be selected considering possible interaction effects discussed in 6.1.3. Selection of devices for sampling ground water is presented in Guide D 4448. Sampling methods and devices should be selected based on the potential impact on sample integrity as addressed in 6.1.3 and other areas in Guide D 4448.

**6.6 Sample Containers**—Sample containers for sampling ground water are addressed in Guide D 4448.

**6.7 Driving or Pushing Equipment**—Soil probing (percussion driving) systems, penetrometer systems, and rotary drilling equipment are used for inserting direct-push water sampling devices. The equipment should be capable of applying sufficient mechanical force or have sufficient reaction weight, or both, to advance the sampler or screen to a sufficient depth to ensure an effective seal above the area to be sampled. The advancement system must also have sufficient retraction force to remove the rods, which is often a more difficult task than advancing the rods. Simple advancement systems include hand-held rotary-impact hammers with mechanical-extraction jacks. Many systems use hydraulic- or vibratory-impact hammers operating at high frequency to drive rods into the sampling interval. Reaction force can be reduced if impact hammers are employed. Multipurpose driving systems such as those commonly deployed for soil gas sampling (Guide D 5314) are frequently used in shallow explorations. Some vibratory drilling systems can provide vibration to the rods and easily penetrate cohesionless soils. On soft ground sites, cone penetrometer systems use hydraulic rams to push the sampler and riser pipe into the ground. Conventional rotary drilling rigs can use either hydraulic pull-down capability or hammers to drive the sampler to the required depth. Rotary drilling rigs are often used with the incremental drilling and sampling method. A 140-lb SPT hammer (Method D 1586) is available on most rotary drilling rigs and can be used to advance the sampler. Use of impact or vibration may allow for penetration of harder soils. If a significant length of rods whip during driving, they

should be restrained to prevent damaging of the annular seal at the base of a borehole from lateral movement.

## 7. Conditioning

**7.1 Decontamination**—Sampling equipment that contacts ground water to be sampled before and after the sampling event may require decontamination. Decontamination should be performed following the procedures outlined in Practice D 5088 and the site-sampling plan. The sampler body normally requires complete decontamination before sampling. Well-screen components are sometimes expendable. Newly manufactured screens and sampler components may contain residues from manufacture and should be cleaned before the sampling event. Riser pipes should be decontaminated if grab sampling will be performed within the tube.

**7.2 Purging**—For exposed-screen sampling devices and sampling systems open to overlying ground water, purging may be required before the sampling event. With both protected- and exposed-screen samplers, purging may be required if ground water from overlying sources infiltrates into the riser pipes into the sampling area. Purging should consist of removal of overlying ground water from the sampling system prior to the sampling event. Purging requirements are outlined in Guide D 4448.

## 8. Procedure

**8.1** Two procedures are outlined depending on whether the sampling device is pushed directly from the surface or whether drilling is used to advance an open hole close to the sampling interval. In either event, the sampling screen should be advanced into undisturbed soil a sufficient distance to ensure that the sampling depth cannot be exposed to overlying ground water, if present.

**8.1.1 Incremental Drilling and Sampling**—In this method, advance a drill hole close to the sampling interval using drilling methods listed in 2.2. Of the drilling methods listed, the most commonly employed is rotary hollow-stem auger drilling because fluids are not introduced during the drilling process. If a rotary drilling method using drilling fluid or air is employed, the impact of the fluid or air to the sample quality and quality of the surrounding aquifer should be considered. If caving or sloughing occurs the use of protective casings may be required.

**8.1.1.1 Stabilize the drill rig and erect the drill rig mast.** Establish and document a datum for measuring hole depth. This datum may consist of a stake driven into a stable ground surface, the top of the surface casing, or the drilling deck. Do not use surface casing as a datum if it is subject to movement. If the hole is to be later surveyed for elevation, record and report the elevation difference between the datum and the ground surface. Proceed with drilling until a depth is reached above the target sampling interval. Check and document the depth of the borehole and condition of the base of the hole. Establish the depth and condition of the base of the boring by resting the sampler at the base of the boring and checking depth to the sampler tip. If casing is used and heave occurs into the casing, remove this material and advance the hole deeper. Heave of soil into the casing may make it impossible to drive the well point without it carrying the casing along with the well point or sampler. If excessive heave, caving, or sloughing of



soil occurs, consider using an alternative drilling method capable of maintaining stable soil conditions.

8.1.2 If the sampling event is to occur at the ground-water table and equipment depends on a dry-hole condition, that is, an exposed screen sampler with no purging requirements, test the drill hole to confirm that ground water has not entered the hole. Water levels can be determined using Test Method D 4750.

8.1.3 Attach the well point or sampler to riser pipes and lower into the borehole. Carefully record the assembly length as rod sections are added to the assembly. Centralizers may be used to maintain verticality of the assembly and to reduce rod whip. Rest the assembly on the base of the borehole. Determine and record the depth to the tip of the assembly.

8.1.4 Either push or drive the well point or sampler a sufficient distance below the base of the boring. This distance should be at least 1 m (3 ft), or the minimum to ensure an effective seal. For protected-screen samplers where a protective screen is exposed by pulling back the riser pipe, the withdrawal action may shear or crack soil, allowing connection to the base of the borehole. In these cases, adjust the insertion and retraction lengths according to soil conditions. In general, the sampler should be inserted at least three times the effective screen length from retraction. To check the seal in fluid filled holes, tracers can be introduced into the fluid in the base of the borehole. Document the final depth of insertion to the tip of the sampler and midpoint of the well screen. If the sampler is driven with hammer blows, accomplish the penetration without excessive vibrations that could reduce the effective seal of the riser pipe above the well screen. Normally, if smooth penetration is accomplished with each hammer blow, the seal should be intact.

8.1.4.1 The process of jetting well points is not preferred because of the addition of water, disturbance to the sampling zone, and lack of an effective seal above the screen. These installations are usually intended for permanent installations with the drill hole completed as a monitoring well. If jetting is used, document the approximate volume and chemical quality of water.

8.1.5 *Sampling*—The sampling process depends on the type of the sampling equipment used, that is, exposed- or protected-screen samplers.

8.1.5.1 *Sampling of Exposed-Screen Samplers*—Exposed-screen samplers can be sampled after fluids have been purged from the screen and riser pipes. Purge these systems in accordance with Guide D 4448.

8.1.5.2 *Sampling of Protected-Screen Samplers*—Test protected-screen samplers that are open to the surface through the riser for grab sampling for system leakage before exposing the screen for sampling. Before screen exposure, test the riser for presence of water that may have leaked through joints and connections using Test Method D 4750. If water is present from unknown sources, this should be noted and either purging or abandoning of the test should be considered. After quality checks for leakage, the riser pipes may be pulled or twisted to expose the well screen to the aquifer.

8.1.5.3 Several methods for sampling water are available. If the sampling device uses head pressure available in the aquifer,

sufficient time should be allowed for water to fill the sampling chamber or riser pipes. Some systems allow for connection of a sealed sampling chamber, or tubing, to a port in the sampler body after the screen is opened, allowing direct connections to the screened sampling area. By using these systems, one may avoid the necessity to check inside the riser pipes for leakage water. Use of sampling pumps to draw in the sample may be allowed, but consideration should be given the changes in ambient pressures and temperatures that may change chemical compositions. With an open tube well screen using grab sampling in low permeability soils, a vacuum is sometimes applied to the top of the riser pipe to accelerate ground-water inflow. The use of a vacuum and its effect on chemical composition should be considered and evaluated if site requirements dictate.

8.1.5.4 After a sufficient volume of the sample is obtained, place the samples in suitable containers for analysis. The volume of a sample to obtain depends on the chemical composition of ground water, testing protocols, and the data-quality objectives. Depending on the screen used, samples may contain sediment and may require filtering before placement of samples in containers. Certain testing procedures or regulations may require filtration of water samples.

8.1.6 After sampling, either retrieve the sampler or leave it in place for permanent installation in accordance with Practice D 5092. Some retrievable samplers leave a tip or a well screen element, or both, below the bottom of the boring. If repeated sampling events are to be performed in the same drill hole, drilling it through these pieces if present will be necessary. Depending on the drilling method, a pilot bit should be reinserted in the drill string and drilling continued to a depth exceeding the depth of the previous sampling event. Normally tips or screens, or both, will be moved to the side of the drill hole before the next sampling event. Sometimes the presence of a tip or element, or both, can be detected by drilling action. If drilling action detects these pieces, note the location. Drilling continues to the next depth of concern and sampling may be repeated. The depth of the extended drill hole should equal or exceed the depth to the sampling tip of the previous interval.

8.1.7 After the drilling is completed, the drill hole should be completed following guidelines in drilling methods (Guides D 5781, D 5782, D 5783, D 5784, D 5785, D 5786, and also see 2.2) or those given in Section 9.

8.2 *Direct Push from the Surface*—Well points and samplers may be advanced directly from the surface with multipurpose percussion driving systems, hand-held rotary percussion drills, cone penetrometer systems, or any other systems capable of supplying sufficient force to reach the depths of concern.

8.2.1 Stabilize and level the rig for testing. For some tire-mounted equipment, the rig can be raised off the ground and leveled with hydraulic rams to lift the rig from the tires to avoid shifting during difficult driving conditions. Establish and document a datum for measuring hole depth. If the hole is to be later surveyed for elevation, record and report the height of the datum to the ground surface.

8.2.2 The sampler body is connected to riser pipes along with any subassemblies such as friction reducers. Prior to driving, measure the length of the sampler assembly and riser



pipes to determine the depth of sampling. Some temporary well systems drive a double tube or cased system, where riser pipe and casing are added as it is advanced. This allows for easy annulus grouting as the casing is retracted. The rods are then shed using smooth quasi static push or impacts, or both. Additional riser pipes are added as pushing progresses. As driving progresses, operators should carefully record the rods added to ensure that sampling occurs at the correct depth.

**8.2.3 Sampling of Exposed-Screen Samplers**—Use the same procedures in accordance with 8.1.5.1.

**8.2.3.1 Sampling of Protected-Screen Samplers**—Use the procedure in accordance with 8.1.5.2 with the addition that the riser pipes should be periodically checked for leakage using Test Method D 4750.

**8.2.4** After sufficient volume of a sample is procured, place the samples in suitable containers for analysis. The volume of the sample to obtain depends on the chemical composition of ground water, testing protocols, and the data-quality objectives. Depending on the screen used, samples may contain sediment and may require filtering before placement of samples in containers.

**8.3** After sampling, the sampler is either retrieved or left in place for permanent installation (Section 9). Some retrievable samplers leave a tip or a well-screen element, or both, at the bottom of the sounding. If repeated sampling events are to be done in the same hole, they must be done with samplers pushed to greater depths.

**8.4** After the testing is finished, complete the borehole following the guidelines in Section 9.

## 9. Completion and Abandonment

**9.1 Permanent or Temporary Well Installations**—Wells inserted by either drilling methods or direct push from the surface may be left in the ground as permanent or temporary installations. Some state or local regulations may not allow for certain types of direct-push installations as permanent monitoring wells depending on the application. If there are questions as to the performance of direct-push wells, they can be compared to wells installed using rotary drilling methods (Guides D 5781, D 5782, D 5783, and D 5784, D5785, D5786, and also see 2.2) in accordance with Practice D 5092. For wells inserted in drill holes, the drill hole will require completion with sealing materials to ensure a seal between the hole wall and riser pipes. Sealing procedures are given Practice D 5092.

**9.1.1** For wells installed by direct push from the surface, the need for sealing depends on the size of the annulus, ground-water quality, and the ability for cross-contaminating or accelerating contamination movements among aquifer(s). Temporary well points installed into the top of the first ground-water layer may only require surface sealing. If the annulus is very small, soil cave and squeeze may reduce effective vertical hydraulic conductivity. If the well riser intersects perched aquifers, cross-communication of aquifers may be possible if too large an annulus is left open. Communication can be evaluated by performing tracer tests, if necessary. Friction reducers used on cone penetrometer equipments may only increase hole diameters by 6 to 13 mm ( $\frac{1}{4}$  to  $\frac{1}{2}$  in.) of that of steel pipes for pushing.

**9.2 Other Completion Methods**—Depending on the require-

ments of the investigation, performing special completions with protective casings or other sealing may be necessary. For holes using rotary drilling methods and incremental sampling, the hole could be completed as a monitoring well (Practice D 5092) or with grouted casings for other testing such as geophysical tests. Several methods are available for grouting of casings. Using injection grouting where injection is done at the base of the boring is most desirable and grouts are pumped up the annulus until they reach the surface showing a continuous seal.

**9.3 Hole Abandonment**—For test holes where there are no installations or other completion methods, the hole should be abandoned following program requirements. The need for and the method of sealing for abandonment depends on state and local regulations, site conditions, ground-water quality, and the ability for cross-contaminating or accelerating contamination movements among aquifer(s).

**9.3.1** Large-diameter drill holes from rotary drill operation often require sealing. State, federal, and local regulations may dictate abandonment requirements for boreholes intersecting the water table.

**9.3.1.1** The need for sealing of holes is also dependent on geohydrologic conditions. If the hole intersects the top of the first ground-water table, complete sealing may not be required. Under a homogeneous single aquifer system, where there are no perched water table or artesian conditions, there will be little hydraulic gradient to move potential contaminants at differing elevations. The worst case for possible cross-communication of aquifers occurs under perched or confined ground-water conditions.

**9.3.1.2** In most cases, direct-push holes intersecting ground-water tables will require complete sealing. In cases where the hole is to be backfilled completely, the condition of the hole should be evaluated and documented. Any zones of caving or blocking which preclude complete sealing should be documented. Displacement grouting may displace ground water from the hole to the surface. If this water is considered contaminated then provisions must be made to collect these fluids at the surface. A minimum requirement for sealing should be that the surface of the hole is sealed to prevent hazards to those at the surface and to eliminate direct movement of surface contaminants to the water table through the hole.

**9.3.2 Completion of Drill Holes**—Completion of boreholes using drilling methods are addressed in Guides D 5781, D 5782, D 5783, D 5784, D 5785, D 5786, and also see 2.2.

**9.3.3 Completion of Surface Direct-Push Holes**—Several methods have been used successfully for sealing or grouting of surface direct-push holes (15). The method of grouting depends on the types of equipment deployed and the subsurface conditions encountered.

**9.3.3.1** One method of grouting is retraction grouting directly through the sampler tip or friction reducer as the sampler is withdrawn after the sampling event. Tip retraction grouting is normally performed through small diameter tubes and a knockoff tip. Tip retraction grouting is the least frequently used due to difficulty in pumping grout mixtures without significant head loss through the tubing. Cement grouts for tip retraction

grouting may require higher water content or additives to reduce viscosity.

9.3.3.2 Retraction grouting is sometimes performed through grouting points above the sampler tip. This is normally accomplished using an enlarged diameter grouting port above the sampler as shown in Fig. 7.

9.3.3.3 Reentry grouting may have an advantage of freeing pushing equipments for production while grouting operations follow. Reentry grouting allows temporary connection of aquifers between the removal and reinsertion process but is normally acceptable if grouting follows promptly minimizing exposure. The selection of retraction or reentry grouting is an economic decision and it depends on site conditions and depth of soundings.

9.3.3.4 In reentry grouting, Fig. 8 and Fig. 9, the test string is completely withdrawn from the hole and a secondary grouting tube or tubing is reinserted to the complete depth of the hole. If the hole remains open after retraction of the test string, inserting flexible tubing or small-diameter PVC into the hole by hand directly after testing may be possible. In this case, reinserting the grout line is desirable close to the original depth of the hole. In some cases, depending on project needs, locations of water bearing strata, and soil stratigraphy, it may be acceptable if the grout line does not reach the bottom of the hole.

9.3.3.5 Usually, with squeezing clays or caving sands, reaction equipment may be required to push rigid tubing of steel or plastic with a sacrificial or grouting tip to the complete

depth of the hole (Fig. 8 and Fig. 9). The reentry string should follow the original hole alignment because it is the path of least resistance. If deviation is suspected, it should be reported. If a knockoff tip is to be retracted in high hydraulic conductivity sands it may be necessary to add grout into rods prior to tip retraction to avoid water filling the rods. Grout is then pumped through the hole until it rises to the surface, or tremie grouting is performed by maintaining a grout column in the rods as they are removed. Grouting is continued to maintain a full hole as tubing is withdrawn. The simplest method of sealing a direct-push hole in stable materials is to place dry materials by pouring or placing directly into the open hole after testing. This method is normally only acceptable in stable clay soils where the hole remains open after testing. This method is not acceptable if there are zones of hole caving or squeezing or there is appreciable presence of ground water in the hole. The holes can be probed with small-diameter rods to evaluate these conditions. Small-diameter granular bentonite is normally used in this application.

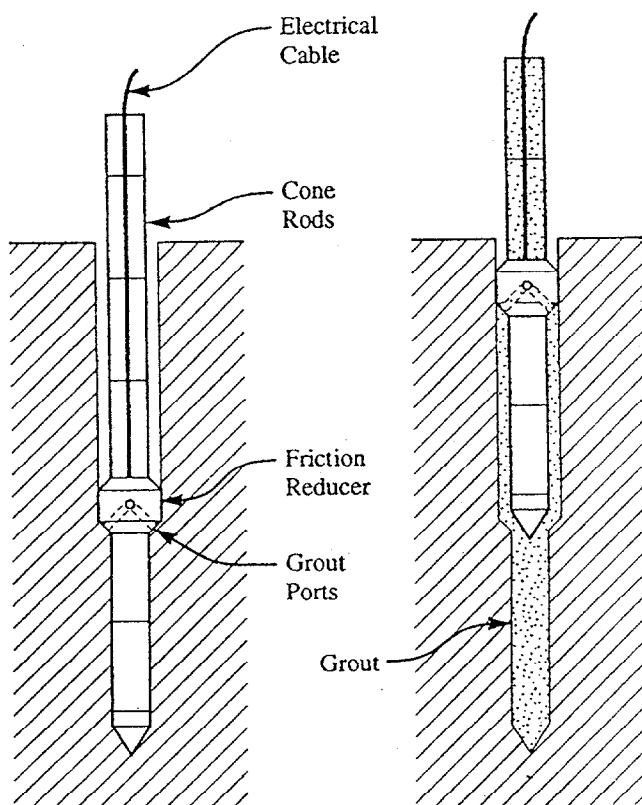
9.3.3.6 Direct-push water sampling holes can be grouted with either cement or bentonite grouts. The grout consistency may have to be wetter than standard mixes used for sealing boreholes (Practice D 5092). There has been no research to confirm the best proportions. A typical mixture is 1 sack of Portland cement to 19 to 22 L (5 to 8 gal) of water. Bentonite is added in a small percentage, 2 to 5 %, to reduce shrinkage. Typical bentonite-based mixtures consist of 22.7 kg of dry powered bentonite to 50 to 200 L (24 to 55 gal) of water. It is difficult to mix dry high-yield bentonite without good circulation equipment and time to allow for mixing and hydration. Pre-hydrated bentonite is easier to mix. Some bentonites contain additives that may not be acceptable for grouting use and the user should check with regulators to ensure sealing products are acceptable.

9.3.3.7 Record the volumes of grout injected and compare them with theoretical hole volumes. Often the grouting pressure at depth is unknown due to head losses through pipes, grout tubing, and connections. Pressure grouting equipments should at a minimum include a pressure gage at the surface. To avoid excessive hydraulic fracturing of the units, downhole pressures should be restricted to  $\frac{1}{2}$  psi per foot of hole depth. Record any unusual changes in grouting pressures that may suggest the presence of obstructions, caved zones, or occurrence of fracturing.

## 10. Field Report and Project Control

10.1 Report information recommended in Guide D 5434 and identified as necessary and pertinent to the needs of the exploration program. Information is normally required for the project, exploration type and execution, drilling equipment and methods, subsurface conditions encountered, ground-water conditions, sampling events, and installations. Some of the data collected during these investigations may be reported as data elements for describing ground-water sites (Guides D 5254, and D 5474).

10.2 Other information besides that mentioned in Guide D 5434 should be considered if deemed appropriate and necessary to the needs of the exploration program. Additional information should be considered as follows:



(a) Installation

(b) Grouting

FIG. 7 Grouting Through Ports In Friction Reducers (15)

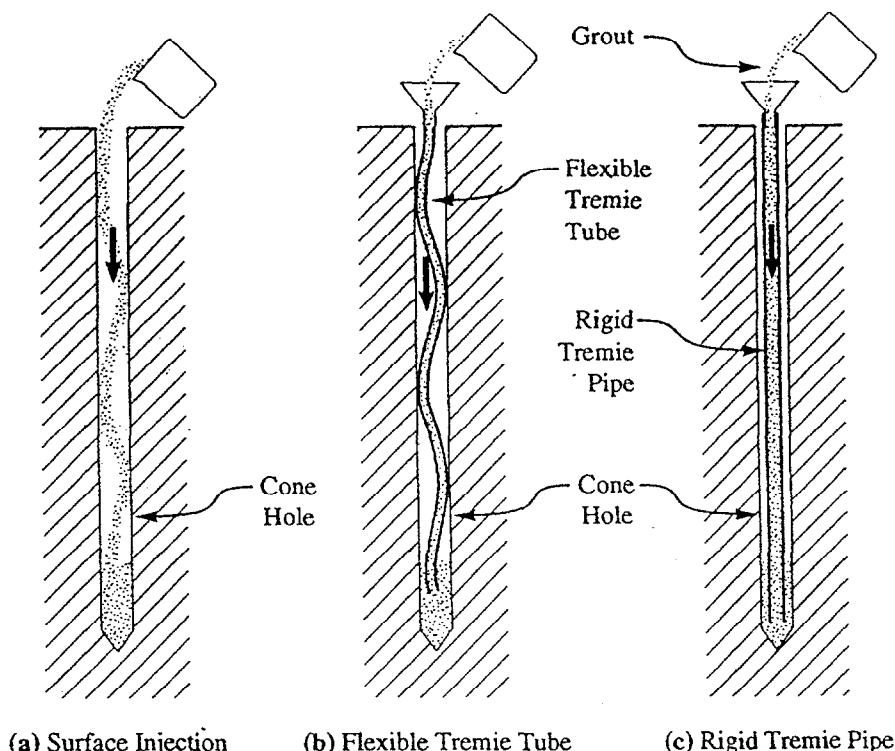


FIG. 8 Rigid Pipe with Internal Flexible Tremie Tube (15)

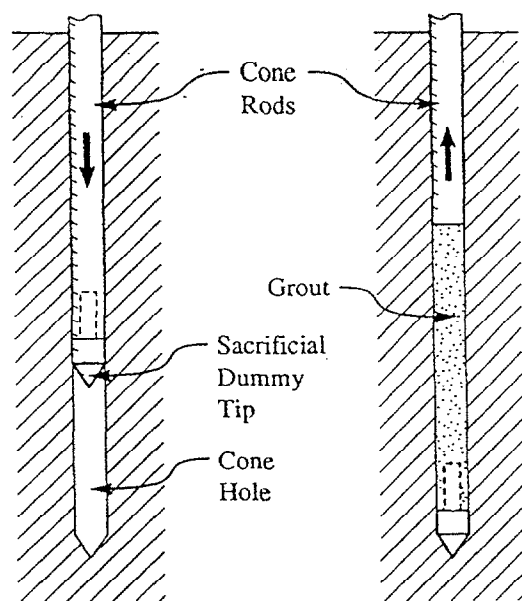


FIG. 9 Reentry with CPT Rods and Sacrificial Tip (15)

10.2.1 *Drilling Methods*—If rotary drilling methods are used for predrilling holes, report information particular to the drilling methods as outlined in Guides D 5781, D 5782, D 5783, D 5784, D 5785, D 5786, and also see 2.2.

10.2.2 *Percussion Driving and Penetrometer Equipment*—For equipment used for surface direct push, report the equipment type, make, model, and manufacturers. Report conditions during push of the sampler such as the occurrence of hard layers. Report datums established for monitoring depth of

penetration. For combined cone penetrometers and water-sampling devices, report cone-penetration information in accordance with Test Methods D 3441 and D 5778.

### 10.3 Sampling:

10.3.1 *Equipment*—Report the types of sampling equipment used including materials of manufacture of the components. Provide dimensions of the equipment including outside diameter, screen length and diameter, and friction reducers. Report methods for cleaning of the equipment before and after sampling. Note materials left in the hole or discarded between sampling events. Report any purging or development actions taken before the sampling event.

10.3.2 When water sampling is performed at the base of the borehole, report the condition of the base of the hole before sampling, and report any slough or cuttings present in the recovered sample.

10.3.3 During insertion of the sampler or well point, note any difficulties in advancing the point and retraction of a protective sleeve. Report the retraction distance for protected-screen samplers. If the sampler cannot be advanced more than the minimum required distance of the sampler given in 8.1.4, report the distance driven. Note and record sampling depths including depths to the tip and midpoint of the well screen. Note any unusual occurrence during sampling such as fluid exposure, or evidence of cross-contamination contained in the samples recovered. Note and record the volume of the sample taken and other sample handling and preservation methods taken.

10.3.4 Report any measurements of water samples routinely performed in the field. These measurements may include temperature, PH, and conductivity. Report methods of testing, calibrations, and equipment used.

**10.4 Completion and Installations**—A description of completion materials and methods of placement, approximate volumes placed, intervals of placement, methods of confirming placement, and areas of difficulty or unusual occurrences.

## 11. Precision and Bias

**11.1** The precision and bias of this method have not been established. Due to variability of subsurface conditions, comparative studies of differing approaches to direct-push sam-

pling have not been statistically significant, because site spatial variability exceeded differences between methods (2). Comparisons between water samples obtained from direct-push samples and standard-monitoring wells have been favorable (11). Additional studies are needed and are actively pursued by Subcommittee D18.21.

## 12. Keywords

12.1 direct-push; water sampling; well point

## REFERENCES

- (1) Cordry, K., "Ground Water Sampling Without Wells," *Proceedings of the National Water Well Association, Sixth National Symposium on Aquifer Restoration and Ground Water Monitoring*, May 19–22, 1986, Columbus, OH, pp. 262–271.
- (2) Zemo, D., et al., "Cone Penetrometer Testing and Discrete-Depth Groundwater Sampling Techniques: A Cost Effective Method of Site Characterization in a Multiple Aquifer Setting," *Proceedings of the National Ground Water Association, Outdoor Action Conference*, May 11–13, 1992, Las Vegas, NV, pp. 299–313.
- (3) Smolley, M., and Kappemyer, J., "Cone Penetrometer Tests and Hydropunch™ Sampling—An Alternative to Monitoring Wells for Plume Detection," *Proceedings of the Hazmacon 1989 Conference*, April 18–20, 1989, Santa Clara, CA, pp. 71–80.
- (4) Berzins, N. A., "Use of the Cone Penetration Test and BAT Groundwater Monitoring System to Assess Deficiencies in Monitoring Well Data," *Proceedings of the National Ground Water Association Outdoor Action Conference*, 1992, pp. 327–341.
- (5) Strutynsky, A., and Bergen, C., "Use of Piezometric Cone Penetration Testing and Penetrometer Groundwater Sampling for Volatile Organic Contaminant Plume Detection," *Proceedings of the National Water Well Association Petroleum Hydrocarbons Conference*, Oct. 31–Nov. 2, 1990, Houston, TX, pp. 71–84.
- (6) Woeller, D. J., Weemees, I., Kokan, M., Jolly, G., and Robertson, P. K., "Penetration Testing for Groundwater Contaminants," *ASCE Geotechnical Engineering Congress, Special Technical Publication*, June 1991.
- (7) Klopp, R. A., Peterson, A. M., and Torstensson, "In-Situ Penetration Testing for Delineation of Ground Water Contaminant Plumes," *Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods*, May 22–25, 1989, National Ground Water Association, Dublin, OH, pp. 329–343.
- (8) Campanella, R. G., Davies, M. P., Boyd, T. J., and Everard, J. L., "In-Situ Teating Methods for Groundwater Contamination Studies," *Developments in Geotechnical Engineering*, Balasubramaniam et al (eds), Balkema, Rotterdam, pp. 371–379.
- (9) Zemo, D. A., Pierce, Y. G., Gallinatti, J. D., "Cone Penetrometer Testing and Discrete-Depth Ground Water Sampling Techniques: A Cost Effective Method of Site Characterization in a Multiple Aquifer Setting," *Ground Water Monitoring Review*, Fall 1994, National Ground Water Association, Dublin, OH, pp. 176–182.
- (10) Eckard, T. L., Millison, D., Muller, J., Vander Velde, E., and Bowallius, R. U., "Vertical Ground Water Monitoring Using the BAT Groundwater Monitoring System," *Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods*, May 22–25, 1989, National Ground Water Association, Dublin, OH, pp. 313–327.
- (11) Church, P. E., and Gvanato, G. E., "Bias in Ground-Water Data Caused by Well Bore Flow in Long Screen Wells," *Ground Water*, March–April 1996, Ground Water Publishing, Columbus, OH, 1996, pp. 262–273.
- (12) Driscoll, F. G., *Groundwater and Wells*, Johnson Filtration Systems Inc., St. Paul, MN, 55112, 1986.
- (13) *Geoprobe Screen Point Ground Water Sampler—Standard Operating Procedure*, Technical Bulletin No. 94-440, Geoprobe Systems, April 1994.
- (14) Schematic Drawings Courtesy of Diedrich Drilling Inc., LaPorte, IN.
- (15) Lutennegger, A. J., and DeGroot, D. J., "Techniques for Sealing Cone Penetrometer Holes," *Canadian Geotechnical Journal*, Vol 32, No. 5, pp. 880–891.

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**APPENDIX H**  
**DECONTAMINATION OF SAMPLING**  
**AND MONITORING EQUIPMENT**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
DECONTAMINATION OF SAMPLING AND  
MONITORING EQUIPMENT**

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**Page 1 of 4  
SOP Number: F502  
Effective Date: 1993**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Sampling Equipment Decontamination Procedures
5.2	Field Analytical Equipment Decontamination
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>



## DECONTAMINATION OF SAMPLING AND MONITORING EQUIPMENT

### 1.0 PURPOSE

The purpose of this SOP is to provide a general methodology and protocol, and to reference information for the proper decontamination of field chemical sampling and analytical equipment.

### 2.0 SCOPE

This procedure applies to all field sampling equipment including, but not limited to, split-barrel soil samplers (split-spoons), direct push samplers, bailers, beakers, trowels, filtering apparatus, and pumps. This procedure should be consulted when decontamination procedures are being developed as part of project-specific plans. Additionally, current USEPA regional procedures and decontamination guidance as well as state guidance should be reviewed.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring field personnel performing decontamination activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of field sampling personnel to follow these procedures, or to follow documented, project-specific procedures as directed by the Field Team Leader.

### 5.0 PROCEDURES

In order to ensure that chemical analysis results reflect actual concentrations present at sampling locations, sampling equipment must be properly decontaminated prior to the field effort, during the sampling program (i.e., between sampling locations) and at the conclusion of the sampling program. This will minimize the potential for cross-contamination between sampling locations and the transfer of contamination off site.

Preferably, sampling equipment should be dedicated to a given sampling location. If this is not possible, equipment must be decontaminated between sampling locations. Sampling personnel must use disposable gloves and change them between sampling locations.

## **5.1 Sampling Equipment Decontamination Procedures**

Soil and sediment sampling equipment including, but not limited to trowels, beakers, dredges, etc., shall be decontaminated using the following USEPA procedures.

### **USEPA**

Prior to use, all sampling equipment should be carefully cleaned using the following procedure:

1. Clean with tap water and laboratory detergent using a brush if necessary to remove particulate matter and surface films.
  2. Rinse thoroughly with tap water.
  3. Rinse with 10 percent nitric acid rinse
  4. Rinse thoroughly with distilled-deionized water and allow to air dry.
  5. Rinse with methanol or hexane and allow to air dry.
  6. Rinse thoroughly with distilled-deionized water and allow to air dry.
  7. Wrap with aluminum foil, if appropriate, to prevent contamination if equipment is going to be stored or transported.
- \* Portable power augers (such as the Little Beaver®) or large soil boring/drill rigs should be cleaned before boring or drilling operations.
  - \* For badly contaminated equipment, a hot water detergent wash may be needed prior to the rinse procedure.
  - \* If the samples will not be analyzed for metals, then steps 3 and 4 may be omitted; if samples will not be analyzed for organics, then step 5 may be omitted. All solvents must be pesticide-grade.

## **5.2 Field Analytical Equipment Decontamination**

Field analytical equipment which may come in direct contact with the sample or sample media, including, but not limited to water level meters, water/product level meters, pH or specific ion probes, specific conductivity probes, thermometers, and/or borehole geophysical probes must be decontaminated before and after use, according to the procedures outlined in Section 5.1, unless manufacturers instructions indicate otherwise. Probes that contact water samples not used for laboratory analyses may be rinsed with distilled water. Probes which make no direct contact (e.g. HNu or OVA probes) will be wiped clean with clean paper towels or an alcohol-saturated cloth.



## 6.0 QUALITY ASSURANCE RECORDS

Decontamination procedures are monitored through the collection of equipment rinsate samples and field blanks. Collection of these samples shall be specified in the project-specific Sampling and Analysis and Quality Assurance Plans. Documentation recorded in the field logbook also shall serve as a quality assurance record.

## 7.0 REFERENCES

U. S. EPA Office of Waste Program Enforcement, 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document (TEGD). OSWER Directive 9950.1.

U. S. EPA, 1991. Standard Operating Procedures and Quality Assurance Manual. Environmental Compliance Branch, U. S. EPA Environmental Services Division, Athens, Georgia.

Micham, J. T., R. Bellandi, E. C. Tifft, Jr., Spring 1989. "Equipment Decontamination Procedures for Ground Water and Vadose Zone Monitoring Programs: Status and Prospects." in Ground Water Monitoring Review.

**APPENDIX I**  
**DECONTAMINATION OF DRILLING RIGS AND**  
**MONITORING WELL MATERIALS**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
DECONTAMINATION OF DRILLING RIGS  
AND MONITORING WELL MATERIALS**

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**Page 1 of 3  
SOP Number: F501  
Effective Date: 1993**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Equipment
5.2	Decontamination Procedures
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## DECONTAMINATION OF DRILLING RIGS AND MONITORING WELL MATERIALS

### 1.0 PURPOSE

The purpose of this SOP is to provide a general reference regarding the proper decontamination of drilling rigs and monitoring well materials used in the performance of field investigations.

### 2.0 SCOPE

This procedure addresses drilling equipment, test pit equipment (i.e. backhoe) and monitoring well material decontamination and should be consulted during the preparation of project-specific plans. This procedure does not pertain to personnel decontamination, or to chemical sampling or field analytical equipment decontamination.

### 3.0 DEFINITIONS

Decontamination - Decontamination is the process of removing or neutralizing contaminants which may have accumulated on field equipment. This process ensures protection of personnel from penetrating substances, reduces or eliminates transfer of contaminants to clean areas, prevents mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

### 4.0 RESPONSIBILITIES

Project Manager - It is the responsibility of the Project Manager to ensure that project-specific plans are in accordance with these procedures. Documentation should be developed for areas where project plans deviate from these procedures.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field. The Field Team Leader is responsible for ensuring the field personnel overseeing decontamination activities, and personnel conducting the activities have been briefed and trained to execute these procedures.

Drilling Inspector (Site Geologist, Rig Geologist etc.) - It is the responsibility of the drilling inspector to ensure that the drilling subcontractor follows these, or other project-specific procedures as directed by the Field Team Leader.

### 5.0 PROCEDURE

The various drilling equipment and materials involved with test boring, test pit excavation, subsurface soil sampling, and monitoring well construction must be properly decontaminated to ensure that chemical analysis results reflect actual concentrations present at sampling locations. These procedures will minimize the potential for cross contamination between sampling locations and the transfer of contamination off site.

## **5.1 Equipment**

All drilling equipment involved in field sampling activities shall be decontaminated prior to drilling, excavation, or sampling activities. Such equipment includes drilling rigs, backhoes, augers, downhole tools, well casings, and screens. Split-spoon soil samplers and other similar soil sampling devices shall be decontaminated according to the procedures given in SOP F502, Decontamination of Sampling and Monitoring Equipment.

## **5.2 Decontamination Procedures**

Prior to drilling, or leaving the site, large equipment not directly utilized for sampling will be decontaminated by steam-cleaning in a designated area. The decontamination procedure consists of steam-cleaning the equipment, using potable water as the steam source, to remove visible signs of soils or wastes, and allowing the equipment to air dry. If necessary, the equipment may be cleaned with a scrub brush andalconox/liquinox-water solution prior to steam cleaning to remove visible signs of contamination.

The steam cleaning area will be designed to contain decontamination wastes and waste waters, and can be a lined, excavated pit or a bermed concrete pad or asphalt pad. For the latter, a floor-drain must be provided which is connected to a holding sump. A shallow, above-surface tank may be used or a pumping system with discharge to a waste tank may be installed.

At certain sites, due to the type of contaminants or proximity to residences, concerns may exist about air emissions from steam cleaning operations. These concerns can be alleviated by utilizing one or more of the following practices:

- Locate the steam cleaning area on site to minimize potential impacts.
- Enclose steam cleaning operations. For example, augers and drilling rods can be steam cleaned in drums. Tarpaulins also can be placed around the steam cleaning area to control emissions.

Decontamination wastes will be collected and contained unless otherwise directed by the Regulatory Agency. The eventual disposition of these wastes will be determined on a project-specific basis, but may include on-site treatment and/or transport off site to an approved treatment/disposal facility.

## **6.0 QUALITY ASSURANCE RECORDS**

Rinsate samples may be collected from steam-cleaned equipment as quality assurance records. The frequency of rinsate samples from either drilling tools or well casings/screens shall be specified in the Sampling and Analysis and Quality Assurance Project Plans for a given project, as appropriate. Documentation in the field logbook also shall serve as a quality assurance record of decontamination activities.

## **7.0 REFERENCES**

None.

**APPENDIX J**  
**ON-SITE WATER QUALITY TESTING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
ON-SITE WATER QUALITY TESTING**

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**Page 1 of 12  
SOP Number: F201  
Effective Date: 04/94**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Measurement of pH
5.2	Measurement of Specific Conductance/Salinity
5.3	Measurement of Temperature
5.4	Measurement of Dissolved Oxygen Concentration
5.5	Measurement of Turbidity
5.6	Measurement of Oxidation Reduction Potential
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

**ATTACHMENT A -- SPECIFIC CONDUCTANCE CONVERSION TABLE**

**ATTACHMENT B -- VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN  
WATER**

**AS A FUNCTION OF TEMPERATURE AND SALINITY**

## ON-SITE WATER QUALITY TESTING (FIELD PARAMETERS)

### 1.0 PURPOSE

This SOP describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance/Salinity
- Temperature
- Dissolved Oxygen Concentration (DO)
- Turbidity (Secchi Disc)
- Oxidation Reduction Potential (ORP)

The first three are the usual field parameters; dissolved oxygen, and ORP, may be used in particular applications according to project requirements.

### 2.0 SCOPE

These procedures are applicable for use in an on-site water quality monitoring program to be conducted during a Remedial Investigation or Site Investigation at a hazardous or nonhazardous site. The procedures and equipment described are applicable to nearly all aqueous samples, including potable well water, monitoring well water, surface water, leachate and drummed water, etc.

This procedure provides generic information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

### 3.0 DEFINITIONS

Conductance - A measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substances in the water. The units of measurement for conductance (mhos) are the inverse of ohms, the unit commonly used to express resistance. Conductivity and specific conductance are used synonymously.

Electrolytic Cell - An electrochemical cell in which electrical energy is supplied from an external source. This cell functions in much the same way as a galvanic cell, only in the opposite direction due to the external source of applied voltage.

Galvanic Cell - An electrochemical cell in which chemical energy is spontaneously converted to electrical energy. The electrical energy produced is supplied to an external circuit.

Oxidation - The process in which an atom or group of atoms loses electrons to achieve an increasing positive charge.



pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration. The range of pH is 0 to 14 standard units.

Resistance - A measure of the solution's ability to oppose the passage of electrical current. For metals and solutions, resistance is defined by Ohm's Law,  $E = IR$ , where E is the potential difference (in units of volts), I is the current (in units of Amperes), and R is the resistance (in units of ohms).

Turbidity - An optical property of water that causes light to be scattered or absorbed in the water, resulting in decrease in water transparency. It is a function of at least three variables: 1) dissolved chemicals, such as tannins, acids, or salts; 2) suspended particles, such as silt, clay, and organic matter; and, 3) density of microbial and planktonic life.

Salinity refers to the total amount of soluble salts in water, either naturally or added to the environment as pollutants.

ORP - Oxidation reduction occurs when electrons are transformed from one atom to another during a chemical reaction. The atom losing electrons is said to be "oxidized", while the atom gaining electrons is termed "reduced". ORP is typically measured using a platinum electrode, attached to a pH meter, which is set to read in millivolt mode.

#### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for determining which on-site water quality measurements shall be made, the data quality objectives (DQOs) for these measurements, and for ensuring that these measurements are made in accordance with project-specific plans.

Field Team Leader - The Field Team Leader is responsible for determining that these water quality measurement procedures are implemented in the field in accordance with this SOP; or in accordance with project-specific plans, and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to follow these procedures for collecting on-site water quality measurements including instrument calibration, quality control and recording of results, as well as care and maintenance of the instruments in the field.

#### **5.0 PROCEDURES**

The following sections provide general procedures for collecting pH, specific conductance/salinity, temperature, dissolved oxygen concentration, turbidity and ORP measurements.

Note: Though there are "multi-parameter" meters on the market today that can simultaneously measure the following parameters, only measurement with "parameter specific" meters will be discussed. If using a multi-parameter meter, all manufacturers instructions for that specific model will be followed for calibration, maintenance and care.

## **5.1 Measurement of pH**

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, such as acid-base neutralization, water softening, and corrosion control, is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Measurements of pH also can be used to check the quality and corrosivity of soil and solid waste samples. However, these samples must be immersed in water prior to analysis; specific measurement techniques for solids are not described here.

### **5.1.1 Principles of Equipment Operation**

Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on the establishment of a potential difference across a glass or other type of membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to hydrogen ion concentration can be generated and measured.

### **5.1.2 Equipment**

The following equipment and reagents are needed for taking pH measurements:

- Laboratory-prepared buffer solutions of pH 4, 7 and 10, or other buffers which bracket the expected pH range.

### **5.1.3 Measurement Techniques for Field Determination of pH**

#### **A. pH Meter**

Standardization, calibration, and operation and maintenance shall be performed according to the manufacturers instructions for the "specific" model being used. The following general procedure is used for measuring pH with a pH meter:

1. The batteries shall be checked to make sure that they are fully charged and the instrument shall be calibrated prior to initiation of the field effort.
2. Immerse the tip of the electrodes in water overnight. If this is not possible due to field conditions, immerse the electrode tip in water for at least an hour before use. The electrode tip may be immersed in a rubber or plastic sack containing buffer solution for field transport or storage.

3. Turn meter on and allow it to stabilize for 3 to 5 minutes.
4. Make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s). Shake electrode as if a mercury thermometer to move air bubbles from the tip to the top.
5. Calibration procedures should be performed:
  - Following significant ambient temperature changes
  - When meter reads erratically
  - At beginning and middle of each day of use
6. When the meter is moved to a new sampling location, a single-point check/calibration should be performed with pH 7 buffer.
7. Immerse the electrode(s) in the unknown solution, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a chemical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
8. After adjusting the temperature compensator to the sample temperature, read and record the pH of the solution. The pH value shall be recorded to the nearest 0.1 pH unit. Also record the sample temperature. All measurements shall be recorded in the Field Logbook.
9. Upon completion of measurement and removal of the electrode from the sample, the electrode shall be thoroughly rinsed with deionized water.
10. The electrode(s) shall remain immersed in storage solution provided, or pH buffer 4 water when not in use.

The sample used for pH measurement shall never be saved for subsequent conductivity or chemical analysis. All pH electrodes leak small quantities of electrolytes (e.g., sodium or potassium chloride) into the solution. Precipitation of saturated electrolyte solution within the electrode, especially at colder temperatures, or in cold water, may result in slow electrode response. Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted in the Field Logbook.

## **5.2 Measurement of Specific Conductance/Salinity**

Conductance provides a measure of dissolved ionic species in water and can be used to suggest the direction and extent of migration of contaminants in groundwater or surface water. Salinity refers

to the total amount of soluble salts in water, either naturally or added to the environment as pollutants. One basic measure of salinity is the ability of water to conduct electric current, and, therefore, a measurement of specific conductance provides a measurement of salinity and the same instrument can be used. Salinity measurements are important in ecological field investigations because flora and fauna can be limited in their distribution based on the salinity of the sampled waters.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance and salinity measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

#### **5.2.1 Principles of Equipment Operation**

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions (cations) migrate toward the negative electrode (cathode), while the negatively charged ions (anions) migrate toward the positive electrode (anode). Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not disassociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell also may be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

#### **5.2.2 Equipment**

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements. A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

#### **5.2.3 Measurement Techniques for Specific Conductance/Salinity**

Standardization, calibration, and operation and maintenance shall be performed according to manufacturers instructions for the "specific" model being used. The general steps involved in taking specific conductance and salinity measurements are listed below.

1. Check batteries to make sure they are fully charged and calibrate instrument before going into the field.
2. Calibrate the instrument daily when used. Potassium chloride solutions with a specific conductance closest to the values expected in the field shall be used. Calibration information shall be recorded in the field logbook.
3. Turn meter on and allow it to stabilize for 3 to 5 minutes.
4. Calibration procedures should be performed:
  - Following significant ambient temperature changes
  - When meter reads erratically
  - At beginning and middle of each day of use
5. Pour approximately 50 to 100 ml of sample into a rinsed plastic cup. Immerse the electrode in the sample and measure the conductivity and salinity. If specified, adjust the temperature setting to the sample temperature.
6. Read and record the results field in the logbook.
7. If the meter does not compensate for temperature variations, the corrections given in Attachment A shall be applied.
8. On some meters, specific conductivity and salinity measurements may need to be reported with the associated temperature measurement. If the conductivity and salinity has been corrected, the measurements shall be reported as "corrected to 25°C." (Attachment A)
  - a. Do not take readings if the sample temperature is less than 10° C, because the calibration curve no longer follows a straight line below this temperature. If necessary, heat the sample in your vehicle to at least 10° C.
  - b. Measure the sample temperature to the nearest 0.1° C to comply with SW-846.
  - c. Only report results to the nearest two significant digits for the most circumstances, because of the inherent inaccuracy in the test and conversion procedure.

examples:

    - a calculated reading of 2353 umhos/cm @ 25° C should be reported as 2400 umhos/cm @ 25° C
    - a calculated reading of 2325 should be reported as 2300
    - a calculated reading of 337 should be reported as 340
    - etc.

### **5.3 Measurement of Temperature**

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field prior to sample collection. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

#### **5.3.1 Equipment**

Temperature measurements may be taken with Thermistor, alcohol-toluene, mercury or bimetal thermometers. In addition, most meters such as specific conductance or dissolved oxygen meters, which have temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature can be performed.

#### **5.3.2 Measurement Techniques for Water Temperature**

If a thermometer is used on a collected water sample:

1. Visually inspect thermometer to ensure that there is not a break in the mercury column. If there is a break, the spare thermometer will be visually inspected. If both thermometers have a break in the mercury, neither will be used until the break is corrected. This will be done by cooling the bulb until the mercury is contained within the bulb.
2. Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
3. Record values in a field logbook to the nearest 0.5 or 0.1 °C, depending on the measurement device used.

If a temperature meter or probe is to be used, the instrument shall be calibrated according to the manufacturer's recommendations with an approved thermometer.

### **5.4 Measurement of Dissolved Oxygen Concentration**

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms, as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time, if the sample is not adequately preserved. Other means of sample preservation may involve directing the sample flow, from the well, directly into a flow cell, which limits sample/air contact.

The method discussed here is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible. DO meters also are free from interference caused by color, turbidity, colloidal material or suspended matter.

#### **5.4.1 Principles of Equipment Operation**

DO probes normally are electrochemical cells that have two solid metal electrodes of different potential immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of higher nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH) occurs at the cathode surface. An electrical current is developed directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, but to leave the surface of the solution undisturbed.

DO probes are relatively free of interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide which are not easily depolarized from the indicating electrode. If gaseous interference is suspected, it shall be noted in the Field Logbook and checked if possible. Temperature, pressure, and salinity variations also can cause interference. Automatic temperature compensation normally is provided by the manufacturer. Attachment B presents variations of DO in water as a fraction of temperature and pressure. Salinity should be compensated in accordance with the manufactures instructions.

#### **5.4.2 Equipment**

A portable conductivity meter, probe and thermometer are needed for taking specific conductance and salinity measurements. A variety of conductivity meters are available which also may be used to monitor salinity and temperatures. Probe types and cable lengths vary, so equipment may be obtained to meet the specific requirements of the sampling program.

#### **5.4.3 Measurement Techniques for Dissolved Oxygen Determination**

Probes differ as to specifics of use. Follow the manufacturer's instructions for the specific model being used to obtain an accurate reading. The following general steps shall be used to measure the DO concentration.

1. Calibrate equipment and check batteries before going to the field.

2. The probe shall be conditioned in a water sample for as long as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
3. The instrument shall be calibrated in the field before each measurement or group of closely spaced measurements by placing the probe in a freshly air-saturated water sample of known temperature.
4. Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane, either by stirring the sample, or placing the probe in a flowing stream. Probes without stirrers which are placed in wells should be moved up and down.
5. Record the dissolved oxygen content and temperature of the sample in a field logbook.
6. Recalibrate the probe when the membrane is replaced, or following similar maintenance, or as needed. Follow the manufacturer's instructions.

Note that in situ placement of the probe is preferable, since sample handling is not involved. This, however, may not always be practical. Be sure to record whether the liquid was analyzed in situ, or whether a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen dissolution and positive test interferences.

## **5.5 Measurement of Turbidity**

Turbidity is caused by fine particles suspended in the water which cause light to scatter, rather than traveling in a straight line. Clay, silt, plankton, and other microorganisms are all examples of particulates that cause turbidity.

Most portable field turbidity meters display results in Nephelometric Turbidity Units (NTU's). This process determines the turbidity level of measuring the amount of light scattered 90° by the suspended particles, by a light of known strength beamed through the solution.

### **5.5.1 Equipment**

A portable turbidity meter, sample vials, standard solutions, and sample cap are typically needed.

### **5.5.2 Measurement Techniques for Turbidity Measurement**

Follow the manufacturers instructions, for the "specific" model being used. The following general steps shall be used to measure turbidity.

1. Calibrate equipment and check batteries, or charge status.



2. Turn on meter and allow to stabilize.
3. Fill a sample vial completely with sample to be obtained, and place cap on vial.
4. Insert vial into light chamber. (Align vial into chamber the same way each time, by making use of tick marks on vial lid). Cover vial with cap.
5. Switch meter to appropriate range and read. Record results into log book.
6. Rinse vials with distilled water between each sample.
7. Calibration procedures should be performed:
  - Following significant ambient temperature changes
  - When meter reads erratically
  - At beginning and middle of each day of use.

## **5.6 Measurement of Oxidation Reduction Potential**

Oxidation reduction occurs when electrons are transformed from one atom to another during a chemical reaction. The atom losing electrons is said to be "oxidized", while the atom gaining electrons is termed "reduced". ORP is typically measured using a platinum electrode, attached to a pH meter, which is set to read in millivolt mode.

### **5.6.1 Equipment**

Though there are ion specific meters for ORP on the market, their very small size and shape do not coincide well with typical multi-parameter set-ups in the field. Typically a pH meter, fitted with a special ORP electrode is used.

### **5.6.2 Measurement Techniques**

At present, only a check solution is available on the market, which is used to verify the performance of the electrode. If the probe reads +/- a certain percentage of the solutions stated value then the electrode is assumed to be in proper working condition.

1. Check batteries and calibrate (check) meter/electrode before heading into the field.
2. Switch pH meter so that it's in the millivolt (mV) mode.
3. Place electrode in sample solution and read results in mV's. Record results in field log book.
4. Rinse electrode with distilled water.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records for on-site water quality management consists principally of observations and measurements recorded in the field logbook.

## 7.0 REFERENCES

American Public Health Association, 1980. Standard Methods for the Examination of Water and Wastewater, 15th Edition, APHA, Washington, D.C.

U.S. EPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020.

U.S. Geological Survey, 1984. National Handbook of Recommended Methods for Water Data Acquisition, Chapter 5: Chemical and Physical Quality of Water and Sediment. U.S. Department of the Interior, Reston, Virginia.

**ATTACHMENT A**  
**SPECIFIC CONDUCTANCE CONVERSION TABLE**

**ATTACHMENT A**  
**SPECIFIC CONDUCTANCE CONVERSION TABLE**

Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier
10	1.402	12	1.330	14	1.266	16	1.208	20	1.106
10.1	1.398	12.1	1.327	14.1	1.263	16.1	1.205	20.1	1.103
10.2	1.394	12.2	1.324	14.2	1.260	16.2	1.202	20.2	1.101
10.3	1.390	12.3	1.320	14.3	1.257	16.3	1.199	20.3	1.099
10.4	1.387	12.4	1.317	14.4	1.254	16.4	1.197	20.4	1.096
10.5	1.383	12.5	1.314	14.5	1.251	16.5	1.194	20.5	1.094
10.6	1.379	12.6	1.310	14.6	1.248	16.6	1.191	20.6	1.092
10.7	1.376	12.7	1.307	14.7	1.245	16.7	1.188	20.7	1.089
10.8	1.372	12.8	1.304	14.8	1.242	16.8	1.186	20.8	1.087
10.9	1.369	12.9	1.301	14.9	1.239	16.9	1.183	20.9	1.085
11	1.365	13	1.297	15	1.236	17	1.180	21	1.083
11.1	1.361	13.1	1.294	15.1	1.233	17.1	1.178	21.1	1.080
11.2	1.358	13.2	1.291	15.2	1.230	17.2	1.175	21.2	1.078
11.3	1.354	13.3	1.288	15.3	1.227	17.3	1.172	21.3	1.076
11.4	1.351	13.4	1.285	15.4	1.225	17.4	1.170	21.4	1.074
11.5	1.347	13.5	1.281	15.5	1.222	17.5	1.167	21.5	1.072
11.6	1.344	13.6	1.278	15.6	1.219	17.6	1.165	21.6	1.069
11.7	1.341	13.7	1.275	15.7	1.216	17.7	1.162	21.7	1.067
11.8	1.337	13.8	1.272	15.8	1.213	17.8	1.159	21.8	1.065
11.9	1.334	13.9	1.269	15.9	1.210	17.9	1.157	21.9	1.063

**Notes:**

- Do not make specific conductance measurements at temperatures below 10° C.
- Measure temperature to the nearest 0.1° C.
- Report all conductivities at 25° C, to two significant digits.
- This conversion table is based on a temperature coefficient of 0.0191 (as per SW-846) and a cell constant of 1, where the ratio of conductivity at 25 C to the conductivity at temperature t° C equals  $1/(1 + 0.0191[t-25])$ .
- The temperature coefficient and cell constants are only approximate, actual values may differ.
- The more the temperature deviates from 25° C, the greater the uncertainty in applying the temperature correction.

**ATTACHMENT A (Continued)**  
**SPECIFIC CONDUCTANCE CONVERSION TABLE**

Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier	Temperature Degrees C	Calculated Multiplier
22	1.061	24	1.019	26	0.981	28	0.946	30	0.913
22.1	1.059	24.1	1.017	26.1	0.979	28.1	0.944	30.1	0.911
22.2	1.057	24.2	1.016	26.2	0.978	28.2	0.942	30.2	0.910
22.3	1.054	24.3	1.014	26.3	0.976	28.3	0.941	30.3	0.908
22.4	1.052	24.4	1.012	26.4	0.974	28.4	0.939	30.4	0.907
22.5	1.050	24.5	1.010	26.5	0.972	28.5	0.937	30.5	0.905
22.6	1.048	24.6	1.008	26.6	0.970	28.6	0.936	30.6	0.903
22.7	1.046	24.7	1.006	26.7	0.969	28.7	0.934	30.7	0.902
22.8	1.044	24.8	1.004	26.8	0.967	28.8	0.932	30.8	0.900
22.9	1.042	24.9	1.002	26.9	0.965	28.9	0.931	30.9	0.899
23	1.040	25	1.000	27	0.963	29	0.929	31	0.897
23.1	1.038	25.1	0.998	27.1	0.961	29.1	0.927	31.1	0.896
23.2	1.036	25.2	0.996	27.2	0.960	29.2	0.926	31.2	0.894
23.3	1.034	25.3	0.994	27.3	0.958	29.3	0.924	31.3	0.893
23.4	1.032	25.4	0.992	27.4	0.956	29.4	0.922	31.4	0.891
23.5	1.029	25.5	0.991	27.5	0.954	29.5	0.921	31.5	0.890
23.6	1.027	25.6	0.989	27.6	0.953	29.6	0.919	31.6	0.888
23.7	1.025	25.7	0.987	27.7	0.951	29.7	0.918	31.7	0.887
23.8	1.023	25.8	0.985	27.8	0.949	29.8	0.916	31.8	0.885
23.9	1.021	25.9	0.983	27.9	0.948	29.9	0.914	31.9	0.884

**Notes:**

- Do not make specific conductance measurements at temperatures below 10° C.
- Measure temperature to the nearest 0.1° C.
- Report all conductivities at 25° C, to two significant digits.
- This conversion table is based on a temperature coefficient of 0.0191 (as per SW-846) and a cell constant of 1, where the ratio of conductivity at 25 C to the conductivity at temperature t° C equals  $1/(1 + 0.0191[t-25])$ .
- The temperature coefficient and cell constants are only approximate, actual values may differ.
- The more the temperature deviates from 25° C, the greater the uncertainty in applying the temperature correction.

**ATTACHMENT B**

**VARIATION OF DISSOLVED OXYGEN CONCENTRATION  
IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY**

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride						
	0	14.6	13.8	13.0	12.1	11.3	0.017
	1	14.2	13.4	12.6	11.8	11.0	0.106
	2	13.8	13.1	12.3	11.5	10.8	0.015
	3	13.5	12.7	12.0	11.2	10.5	0.015
	4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014	
6	12.5	11.8	11.1	10.5	9.8	0.014	
7	12.2	11.5	10.9	10.2	9.6	0.013	
8	11.9	11.2	10.6	10.0	9.4	0.013	
9	11.6	11.0	10.4	9.8	9.2	0.012	
10	11.3	10.7	10.1	9.6	9.0	0.012	
11	11.1	10.5	9.9	9.4	8.8	0.011	
12	10.8	10.3	9.7	9.2	8.6	0.011	
13	10.6	10.1	9.5	9.0	8.5	0.011	
14	10.4	9.9	9.3	8.8	8.3	0.010	
15	10.2	9.7	9.1	8.6	8.1	0.010	
16	10.0	9.5	9.0	8.5	8.0	0.010	

Temperature °C	2.Dissolved Oxygen mg/l 2.1.Chloride Concentration in Water 2.1.1.0 2.1.2.5,000 2.1.3.10,000 2.1.4.15,000 2.1.5.20,000 2.2.Difference/ 100 mg chloride					
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008



**APPENDIX K**  
**WATER LEVEL, WATER-PRODUCT LEVEL**  
**MEASUREMENTS, AND WELL DEPTH MEASUREMENTS**

**WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND  
WELL DEPTH MEASUREMENTS  
TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Water Level Measurement
  - 5.2 Groundwater-Product Interface Level Measurement
  - 5.3 Well Depth Measurements
  - 5.4 Decontamination of Measuring Devices
- 6.0 QUALITY ASSURANCE RECORDS**

## **WATER LEVEL, WATER-PRODUCT LEVEL MEASUREMENTS, AND WELL DEPTH MEASUREMENTS**

### **1.0 PURPOSE**

The purpose of this procedure is to describe the method of determining various down-hole measurements: groundwater levels and product (or non-aqueous phase liquid, NAPL) levels, if present, and total depth of groundwater monitoring wells and piezometers.

### **2.0 SCOPE**

The methods described in this SOP generally are applicable to the measurement of groundwater levels, product or NAPL levels, and well depths in monitoring wells and piezometers.

### **3.0 DEFINITIONS**

None.

### **4.0 RESPONSIBILITIES**

**Project Manager** - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed.

**Field Team Leader** - The Field Team Leader is responsible for ensuring that these procedures are implemented in the field, and for ensuring that personnel performing these activities have been briefed and trained to execute these procedures.

**Sampling Personnel** - It is the responsibility of the sampling personnel to follow these procedures or to follow documented, project-specific procedures as directed by the Field Team Leader and/or the Project Manager. The sampling personnel are responsible for the proper acquisition of down-hole measurements.

### **5.0 PROCEDURES**

Calculations of groundwater elevations and product or NAPL interface level measurements collected from a monitoring well give an indication of:

- The horizontal hydraulic gradient and the direction of groundwater flow.
- The vertical hydraulic gradient, if well nests are used (i.e., the direction of groundwater flow in the vertical plane).

- Floating or sinking product thicknesses which are also known as Light Non-Aqueous Phase Liquids (LNAPLS) and Dense Non-Aqueous Phase Liquids (DNAPLS), respectively.

This information, when combined with other site specific information such as hydraulic conductivity or transmissivity, extent of contamination, and product density, may be used to estimate the rate of contaminant movement or source areas, etc.

Well depth is one of the factors used to determine the zone that a well monitors. Well depth also is used in the calculation of purge volumes as discussed in SOP F104, Groundwater Sample Acquisition.

The following sections briefly discuss the procedures for measuring groundwater levels, product or NAPL levels, and well depth. For all of the procedures discussed, it is assumed that the measurement will be taken from the top of the PVC or stainless steel casing (though other measuring points can be used), and that horizontal and vertical control is available for each well through a site survey, such that measurements may be converted to elevations above Mean Sea Level (MSL) or some other consistent datum. A permanent notch, placed on the inner PVC or stainless steel casing by the surveyor will facilitate consistent water level measurements.

The manufacturer's instructions for all equipment referenced herein should be read by the equipment operator(s) and accompany the equipment to the field.

### **5.1 Water Level Measurement**

Water levels in groundwater monitoring wells shall be measured from the permanent point indicated at the top of the inner casing (the surveyed elevation point, as marked by the surveyor), unless otherwise specified in the project plans, using an electronic water level measuring device (water level indicator). The point of measurement will be documented in the field logbook if different from the top of the inner casing. The reason for deviating from the measurement point should also be noted.

Water levels are measured by lowering the probe into the well until the device indicates that water has been encountered, usually with either a constant buzz, or a light, or both. The water level is recorded to the nearest foot (0.01) using the graduated markings on the water level indicator cord. This measurement, when subtracted from the measuring point elevation, yields the groundwater elevation.

Groundwater levels shall always be measured to the nearest 0.01 foot. However, reporting of water level elevations depends on the accuracy of the vertical control (typically either 0.1 or 0.01 foot).

### **5.2 Product or NAPL Level Measurements**

The procedure for product or NAPL level measurement is nearly identical to that for groundwater elevation measurements. The only differences are the use of an interface probe that detects both NAPLs and water, and the indication signal given by the measurement device. Typically, encountering NAPLs in a monitoring well is indicated by a constant sound. When water is encountered, the signal

becomes an alternating on/off beeping sound. This allows for the collection of measurements for both the top of the NAPL layer in a well and the water/NAPL interface.

The apparent water table elevation below the product level will be determined by subtracting the "depth to water" from the measuring point elevation. The corrected water table elevation will then be calculated using the following equation:

$$WTE_c = WTE_a + (\text{Free Product Thickness} \times 0.80)$$

Where:

$WTE_c$	=	Corrected water table elevation
$WTE_a$	=	Apparent water table elevation
0.80	=	Average value for the density of petroleum hydrocarbons. Site-specific data will be used where available.

### 5.3 Well Depth Measurements

Well depths typically are measured using a weighted measuring tape. A water level meter may also be used. The tape is lowered down the well until resistance is no longer felt, indicating that the weight has touched the bottom of the well. The weight should be moved in an up and down motion a few times so that obstructions, if present, may be bypassed. The slack in the tape then is collected until the tape is taut. The well depth measurement is read directly off of the measuring tape, at the top of the PVC or stainless steel casing, to the nearest 0.01-foot and recorded in the Field Logbook. If a water level indicator is used, add the distance from the bottom of the probe to the point where water levels are measured.

### 5.4 Decontamination of Measuring Devices

Water level indicators, interface probes and weighted measuring tapes that come in contact with groundwater must be decontaminated using the following steps after use in each well:

- Rinse with potable water
- Rinse with deionized water
- Rinse with Methanol or Isopropanol
- Rinse with deionized water

Portions of the water level indicators or other similar equipment that do not come into contact with groundwater, but may encounter incidental contact during use, need only undergo potable water and deionized water rinses. Decontamination fluids will be collected in 55-gallon drums.

## **6.0 QUALITY ASSURANCE RECORDS**

The Field Logbook shall serve as the quality assurance record for water, product level or well depth measurements.



**APPENDIX L**  
**PHOTOIONIZATION DETECTOR (PID)**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
PHOTOIONIZATION DETECTOR (PID)**

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**Page 1 of 7  
SOP Number: F203  
Effective Date: 04/94**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Calibration
5.2	Operation
5.3	Interferences and Potential Problems
5.4	Maintenance
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>



## **PHOTOIONIZATION DETECTOR (PID) HNu MODELS PI 101 and DL 101**

### **1.0 PURPOSE**

The purpose of this SOP is to provide general reference information for using the HNu Model PI 101 or DL 101 photoionization detector (PID), or an equivalent or similar instrument, in the field. Calibration and operation, along with field maintenance will be included in this SOP.

### **2.0 SCOPE**

This procedure provides information on the field operation and general maintenance of the HNu PID. Application of the information contained herein will ensure that this type of field monitoring equipment will be used properly. Review of the manufacturer's instruction manual is necessary for more complete information.

These procedures refer only to monitoring for health and safety. The methods are not directly applicable to surveillance of air quality for analytical purposes.

### **3.0 DEFINITIONS**

Ionization Potential - In this case, a numeric equivalent that expresses the amount of energy needed to replace an electron with a photon. This energy is further defined in terms of electron volts (eV).

PID - Photoionization Detector

ppm - parts per million: parts of vapor or gas per million parts of air (directly proportional to calibration gas).

### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in both the Field Logbook and the daily Realtime Air Monitoring Log during each field investigation.

## **5.0 PROCEDURES**

The HNu PID utilizes the principle of photoionization whereby contaminant molecules enter the ion chamber and electrons are displaced by ultraviolet photons producing positive ions. These displaced positive ions are in turn collected on a special electrode. As the positive ions collect on the electrode, they create an electrical current which is amplified and displayed on the meter as a concentration in parts per million (ppm).

The HNu PID is only effective for contaminants that have ionization potentials (IP) of less than or equal to the electron volt (eV) capacity of the lamp (i.e., methane, having an IP of 12.98 eV, will not be detected at a lamp potential of 11.7 eV). The standard lamp is 10.2 eV with optional lamps of 9.5 eV and 11.7 eV, respectively. For the PI 101 the span settings should be as follows: 1.0 for 9.5 eV lamps; 9.8 for 10.2 eV lamps; and 5.0 for 11.7 eV lamps. During calibration, these span settings will be adjusted as necessary, using the span control knob.

The following subsections will discuss HNu PID calibration, operation, and maintenance. These sections, however, should not be used as a substitute for the manufacturer's instruction manual.

### **5.1 Calibration**

For calibration purposes, the following items will be needed:

- Gas cylinder containing 95 to 100 parts per million (ppm) of isobutylene, balance in air.
- A 0.30 liters per minute regulator.
- Connector tubing.
- Screwdriver set.
- Photoionization Detector (PID) Calibration Form.

Prior to each use, make sure that the battery is fully charged, the ultraviolet lamp is working, and that the fan is operating and drawing air into the probe (fan operates at approximately 100-200 cc/minute for the PI 101 and 225 cc/minute for the DL 101). Procedures for completing these preliminary activities are given in the manufacturer's instruction manual.

#### **PI 101**

To calibrate the PI 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 3-5 in the manufacturer's instruction manual. The PI 101 should be calibrated on a daily basis.

- Turn the function control switch to the standby position and zero the instrument by turning the zero adjustment knob to align the indicator needle with zero on the readout meter.

- Set the range on the PI 101 and allow the instrument to warm up a few minutes before calibrating. Choices for range are 0-20, 0-200, and 0-2,000 ppm, respectively. Range choice must take into account the concentration of the calibration gas. For example, if you are using a concentration of 100 ppm isobutylene as the calibration gas, your range should be set on the 0-200 scale. If you have to zero the instrument in the desired range, record background if present.
- Attach tubing to the regulator
- Attach the free end of the tubing to the probe and turn on the calibration gas.
- Calibrate the PI 101 to benzene equivalents. Using the 10.2 eV (lamp) probe and 100 ppm isobutylene, the meter should read 56 units. Using the 11.7 eV (lamp) probe and 100 ppm isobutylene, the meter should read 65 units. If the reading on the meter is not  $\pm 5$  percent of the concentration of the calibration gas, adjust the span setting knob until the meter reads accordingly. If after adjusting the span setting knob the readout meter is still not responding, refer to the manufacturer's instruction manual. Also, when the PI 101 is calibrated it should respond to a minimum of 90 percent of the concentration of the calibration gas within three seconds after introduction of that gas. If proper calibration cannot be obtained, internal calibration may be required. Note, only qualified personnel should perform internal calibrations.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form".

### **DL 101**

To calibrate the DL 101, the steps provided below should be followed. For an itemized description of the calibration process, refer to Section 4.4 in the manufacturer's instruction manual.

- Press and release the POWER button on the keypad and wait for the screen to stabilize then press the CALIBRATE key until "Calibrate?" appears. At this point press the ENTER key until "Elec\_Zero? Yes" appears on the screen in which case you will press the ENTER key, again, to confirm the electronic zero.
- The display will now read "CE/ENT/EXIT Conc = \_\_\_\_ ppm" which requires the concentration of the calibration gas (noted on the side of the calibration gas bottle) to be entered on the keypad. The display will prompt you to "Attach gas to probe and /ENTER/" so attach tubing to probe (use the calibration gas humidifier in high humidity environments), open valve, and press ENTER key. Press ENTER again when "Press ENTER when Ready: xxx ppm" appears on screen. This will cause "Calibrating...Please Wait" to appear on screen.

Note: This calibration is effective when the instrument is in the Survey Mode, which is the default mode. For calibrations other the one described, or if proper calibration cannot be obtained, refer to the manufacturer's instruction manual.

- For calibrations using an alternate gas or span values, refer to Section 4.5 of the manufacturer's instruction manual.
- Record the calibration on the "Photoionization Detector (PID) Calibration Form" which accompanies each DL 101.

## 5.2 Operation

### PI 101

Note: IMPORTANT - The PI 101 should be "zeroed" in a fresh air environment if at all possible. If there is a background concentration, it must be documented and then zeroed out.

- Prior to each use of the PI 101, check that the battery is fully charged by turning the dial to BATT and making sure that it is within range. Also make sure that the ultraviolet lamp and the fan are working properly.
- Select your desired range. PI 101 ranges consists of a 0-20, 0-200, and 0-2,000 ppm, respectively. Consult with the Field Team Leader for more information when choosing the appropriate range, however, in most instances the range will be set initially at 0-20.
- When PI 101 is used intermittently, turn knob to STANDBY to help in extending the life of the UV lamp when operating in a low humidity environment. Otherwise, leave the knob set to the range desired so that the UV lamp will "burn off" any accumulated moisture.

Note: When using the PI 101, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

### DL 101

The DL 101 is designed to default to the survey mode when initially powered up, therefore once the calibration has been completed, the instrument is ready to go. Within the survey mode several options are available, briefly these options include:

#### 1. The Site Function

The Site function assigns a number to a site that is being analyzed. Press the Site Key on the keypad to enter a specific site number, or press the gray button on the rear of the probe to increment a site number.

#### 2. Logging Data

The Log function stores data in memory. To log data, press the Log key on the keypad or the Log button on the back of the probe. "Log" will appear in the upper right corner of the display when activated and disappears when not activated. To turn logging off, press either the Log key on the keypad or the red Log button on the rear of the probe.

- The DL 101 allows for the interchanging of different voltage lamps, however, refer to the manufacturer's instructions before attempting to change the lamp.
- The DL 101 also offers three other modes of operation, the Hazardous Waste Mode, the Industrial Hygiene Mode, and the Leak Detection Mode. Each of these modes increases the range of capabilities for this instrument which is covered in detail in the manufacturer's instruction manual.

Note: When using the DL 101, make sure that the probe does not contact water or soil during sampling. This will cause erroneous readings and will possibly damage the instrument.

### 5.3 Interferences and Potential Problems

A number of factors can affect the response of the PI 101 and DL 101.

- High humidity can cause lamp fogging and decreased sensitivity. This can be significant when soil moisture levels are high, or when monitoring a soil gas well that is accessible to groundwater.
- High concentrations of methane can cause a downscale deflection of the meter.
- High and low temperature, electrical fields, FM radio transmission, and naturally occurring compounds, such as terpenes in wooded areas, will also affect instrument response.

### 5.4 Maintenance

The best way to keep an HNu PID operating properly is to keep it as clean as possible. HNu PID's should be decontaminated or wiped down daily or after each use, as appropriate.

#### **Corrective Maintenance**

- The ultraviolet lamp should be periodically cleaned using a special compound supplied by HNu Systems, Inc. for the 10.2 eV lamp, and a chlorinated solvent such as 1,1,1-trichloroethane for the 11.7 eV lamp. Consult the manufacturer's instruction manual for specific cleaning instructions.
- The ionization chamber can be periodically cleaned with methyl alcohol and a swab.

Note: UV lamp and ion chamber cleaning is accomplished by following the procedures outlined in Section 5.2, however, this should only be performed by trained personnel.

- Documenting the HNu PID's observed symptoms and then referring to the manufacturer's instruction manual section on troubleshooting (Section 6.0) also can be employed. If this does not work, the Field Team Leader should be consulted for an appropriate course of action.

Repair and Warranty Repair - HNu PID's have different warranties for different parts, so documenting the problem and sending it into the manufacturer assists in expediting repair time and obtaining appropriate warranty service.

### **5.5 Shipping and Handling**

Following is information regarding the transport of the HNu PID meter and calibration gas.

- If the HNu PID is to be carried on aircraft, the calibration gas must be removed from the carrying case as cylinders of compressed gas are not permitted on passenger aircraft. The calibration gas should either be shipped to the site of its intended use, or purchased locally.
- Shipping of the calibration gas requires the completion of a form (specified by the shipping company) that identifies the package as a compressed gas. Compressed gas stickers must be affixed to the package.

### **6.0 QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, location, activity monitored, (surface water sampling, soil sampling, etc.) serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the HNu PID meter had wide range fluctuations during air monitoring activities).

### **7.0 REFERENCES**

HNu Systems, Inc. Instruction Manual. Model PI 101, 1986.  
HNu Systems, Inc. Operator's Manual. Model DL 101, 1991.

**APPENDIX M**  
**BACHARACH COMBUSTIBLE**  
**GAS/OXYGEN METER AND PERSONAL**  
**GAS MONITOR CARBON MONOXIDE METER**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
BACHARACH COMBUSTIBLE GAS/  
OXYGEN METER PERSONAL GAS MONITOR**

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**Page 1 of 6  
SOP Number: F208  
Effective Date: 04/94**

**TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Calibration
  - 5.2 Operation
  - 5.3 Site Maintenance
  - 5.4 Scheduled Maintenance
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**



## **BACHARACH COMBUSTIBLE GAS/ OXYGEN METER AND PERSONAL GAS MONITOR**

### **1.0 PURPOSE**

The purpose of this SOP is to provide general reference information for using the Bacharach Sentinel 4 and Bacharach Sniffer® 503-A meters in the field. Calibration and operation, along with field maintenance, will be included in this SOP.

### **2.0 SCOPE**

This procedure provides information into the field operation and general maintenance of the Sentinel 4 Sniffer and 503-A. Review of the information contained herein will ensure that this type of field monitoring equipment will be properly utilized. Review of the owner's instruction manuals is a necessity for more detailed descriptions.

### **3.0 DEFINITIONS**

Carbon Monoxide Sensor - Expresses the Carbon Monoxide concentration in parts per million (ppm).

Combustible Gas - Combustible gas is expressed as a percent of the lower explosive limit (LEL).

Hydrogen Sulfide Sensor - Expresses the Hydrogen Sulfide concentration in parts per million (ppm).

Oxygen Sensor - Expresses the Oxygen concentration as a percentage.

ppm - parts per million: parts of vapor or gas per million parts of air by volume.

Sentinel 4 - Combustible Gas/Oxygen/Hydrogen Sulfide/Carbon Monoxide meter.

Sniffer 503-A - portable Combustible Gas and Oxygen Alarm instrument.

### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project -specific plans are in accordance with these procedures, where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the monitoring activities.

Project Health and Safety Officer (PHSO) - The Project Health and Safety Officer is responsible for developing a site-specific Health and Safety Plan (HASP) which specifies air monitoring requirements.

Field Team Leader - It is the responsibility of the Field Team Leader to implement these procedures in the field, and to ensure that the Field Investigation Personnel performing air monitoring activities, have been briefed and trained to execute these procedures before the start of site operations.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the specified air monitoring equipment is on site, calibrated, and used correctly by the Field Personnel. The SHSO will coordinate these activities with the Field Team Leader.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader/Site Health and Safety Officer. The Field Investigation Personnel are responsible for documenting all air monitoring results in the Field Logbook during each field investigation.

## 5.0 PROCEDURES

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A utilize the principle of detecting sensors. The following four paragraphs discuss theory of operation as it applies to each functional sensor.

The combustible gas sensor uses two elements that are wound with a platinum wire. One of the elements is impregnated with a catalyst to oxidize combustible gases. The other element is impregnated with material that will also oxidize combustible gases, but will respond to temperature and humidity conditions. When the meter is turned on, an electrical current is passed through the elements and wires. As a combustible gas enters the chamber the elements will oxidize the combustible gas, thus increasing the heat and resistance of the element. This change in resistance causes a system imbalance, which produces a measurable signal proportional to the combustible gas concentration.

The percent oxygen is measured utilizing an electrochemical sensor. As atmospheric oxygen enters the meter it diffuses into the sensor which converts the amount of oxygen in the sensor to a voltage signal. This voltage is directly proportional to percent oxygen in the atmosphere.

The concentration of hydrogen sulfide is measured utilizing an electrochemical sensor. As atmospheric hydrogen sulfide enters the meter it diffuses into the sensor which converts the amount of hydrogen sulfide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric hydrogen sulfide concentration.

The concentration of carbon monoxide as measured utilizing an electrochemical sensor. As atmospheric carbon monoxide enters the meter it diffuses into the sensor which converts the amount of carbon monoxide in the sensor to a voltage signal. This voltage is directly proportional to the atmospheric carbon monoxide concentration.

The Sentinel 4 Personal Gas Monitor and Sniffer 503-A are intrinsically safe for use in Class I, Division 1, Groups A, B, C and D hazard areas. One fact that needs to be expressed is that this type of monitoring equipment utilizes internal oxidation of combustibles, if the meter is placed in an oxygen deficient atmosphere, the combustible reading may be affected. Review of each of the instruction manuals will aid in determining the percentage of oxygen that affects the combustible gas readings.

The following subsections will discuss Sentinel 4 and Sniffer 503-A calibration, operation, and maintenance. These sections, however, do not take the place of the instruction manual.

## **5.1 Calibration**

### **Sentinel 4**

Due to the numerous steps involved in calibration, it is recommended that you follow the calibration procedures (on a daily basis) as outlined in the instruction manual from pages 5-12 to 5-20.

NOTE: A calibration kit will be provided for each Sentinel 4. This kit contains a cylinder for the combustible gas sensor, one cylinder for the hydrogen sulfide sensor, and one cylinder for the carbon monoxide sensor. The oxygen sensor can be calibrated with (uncontaminated/fresh air environment) atmospheric air and does not need cylinder gas.

Note: When a single sensor doesn't zero, none of the sensors are zeroed.

### **Sniffer® 503-A**

#### **Oxygen Detector**

1. Check battery charge by turning function switch to "BATTERY TEST," if battery is in recharge zone instrument will need to be charged.
2. To zero the oxygen detector, turn function switch to "BATTERY TEST" position and press "TEST" switch and observe the O<sub>2</sub> meter indication. If indicator is zero, no further adjustment is necessary. If not, follow procedures in Section 5.4.1 of the Operations Manual.
3. To calibrate the oxygen detector, turn function switch to "BATTERY TEST" position. Unlock the "OXYGEN CALIB" knob and adjust it for an O<sub>2</sub> meter indication of 21 or at the CAL mark. Relock "OXYGEN CALIB" knob. If using zero calibration gas, follow procedures in Section 5.4.2 of the Operator's Manual.
4. Record on Calibration Sheet.

#### **% LEL Detector**

1. Check battery charge by turning function switch to "BATTERY TEST," if batter is in recharge zone, instrument will need to be charged. Allow 5 minutes for the instrument to warm up.
2. Turn function switch to the % LEL position.

Note: To eliminate the annoyance of the audible alarm, cover the alarm with a hand or duct tape during calibration. The tape must be removed, prior to operation!!

3. Connect calibration gas (typically 30% of the LEL) and allow gas to flow for 1 minute.

Note: If calibration gas has a concentration value, not a % LEL value, the % LEL can be calculated as follows:

$$\% \text{ calibration gas (i.e., methane)} \times 20\% \text{ LEL (meter alarm setting)} = \% \text{ LEL calibration setting}$$

If meter indication is within  $\pm 5\%$  of LEL calibration gas, no further adjustment is required. If not, follow procedures in Section 5.5.4 of Operator's Manual.

### **Sniffer® 503-A**

1. Connect sample probe and tubing to the instrument's sample inlet (refer to Sections 8.4 and 8.5 for the Operator's Manual for available hoses and probes).
2. Check that battery is in Operational Range.
3. Turn instrument to % LEL range and allow to warm up for 1 minute.
4. Check in a fresh air environment that % LEL reads 0% and that O<sub>2</sub> indicator reads 21% (calibration mark).
5. Sample air/gas from area to be tested, allow 30 seconds for readings to stabilize. When finished, allow at least 10 seconds (longer if extension line is used) to purge sample line.
6. If instrument is operating erratically, refer to "TROUBLESHOOTING" Section (Table 5-2) in Operator's Manual.

## **5.2 Operation**

### **Sentinel 4**

Due to the Sentinel 4 having many functions in terms of operation, it is recommended that you follow the operational procedures as outlined in the instruction manual from pages 6-1 to 6-34.

NOTE: Since the Sentinel 4 is capable of measuring four different parameters, an understanding of the alarm, error, and fault messages must be obtained. This can be done by reviewing the troubleshooting table found on pages 9-2 to 9-9.

## **5.3 Site Maintenance**

After each use, the meters should be recharged and the outside of the instruments should be wiped clean with a soft cloth.

#### 5.4 **Scheduled Maintenance**

<u>Function</u>	<u>Frequency</u>
Check alarm and settings	Monthly/before each use
Clean screens and gaskets around sensors	Monthly
Replace sensors	Biannually or when calibration is unsuccessful

#### 6.0 **QUALITY ASSURANCE RECORDS**

Quality assurance records will be maintained for each air monitoring event. The following information shall be recorded in the Field Logbook.

- Identification - Site name, date, location, CTO number, activity monitored, (surface water sampling, soil sampling, etc), serial number, time, resulting concentration, comments and identity of air monitoring personnel.
- Field observations - Appearance of sampled media (if definable).
- Additional remarks (e.g., the Sentinel 4 or Sniffer 503-A had wide range fluctuations during air monitoring activities.)

NOTE: The "Toxic Gas Meter Calibration Form" will be completed daily, prior to performing any air monitoring.

#### 7.0 **REFERENCES**

Bacharach Installation, Operation, Maintenance Manual, Sentinel 4 Personal Gas Monitor, 1990.  
Bacharach Installation, Operation, Maintenance Manual, Sniffer® 503-A, Rev. 3 - October, 1990.

**APPENDIX N**  
**LAND SURVEY**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
LAND SURVEYING**

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**Page 1 of 4  
SOP Number: F801  
Effective Date: 1993**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
<b>6.0</b>	<b>HEALTH AND SAFETY</b>
<b>7.0</b>	<b>QUALITY ASSURANCE RECORDS</b>

## LAND SURVEYING

### 1.0 PURPOSE

This procedure describes methods and equipment commonly used by a Registered Land Surveyor when compiling by survey the vertical and horizontal locations of on-site monitoring wells and other site structures, and topographic features associated with study areas at various locations.

### 2.0 SCOPE

The information presented in this SOP is generally applicable to various locations, except where state-specific requirements differ concerning certifications, licenses and registrations.

Specific surveying problems encountered by the survey crew may require the adaptation of existing equipment or design of new equipment. Such innovations shall be documented in the survey crew's Field Logbook.

### 3.0 DEFINITIONS

North American Datum (AND) - Datum used during the absence of established horizontal and vertical control.

Mean Sea Level (MSL) - Adopted as a datum plane for the measurement of elevations and depths.

Horizontal Control - Horizontal location of an object from surveyed corners or other features on permanent land monuments in the immediate site area. Will be based on North American Datum (AND).

Vertical Control - Vertical location of an object compared to the adjacent ground surface.

Bench Mark - Precisely determined elevation above or below sea level. May also have horizontal control (northing, easting) determined for location.

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with acceptable surveying practices as required by the state in which the work is performed.

Field Team Leader - The Field Team Leader is responsible for ensuring that procedures are implemented in the field and that personnel performing surveying activities have been briefed and trained to execute these procedures.

### 5.0 PROCEDURES

Baker requires the services of a Registered Land Surveyor to determine by survey the elevations and horizontal locations of monitoring wells and other site structures, and topographic features associated with study areas at various locations. The surveyor will mobilize to the site within seven days upon receiving the notice-to-proceed. All site surveys must be completed in the time frame agreed upon. The site map shall be completed within ten days of completion of the site survey.



## 5.1

Specifically, Baker requires the following:

Delineate the elevations of groundwater monitoring wells to an accuracy of 0.01 feet, referenced to United States Geological Survey Mean Sea Level (MSL) from the nearest datum bench mark.

### 5.1.1

The elevation point for each well casing and a permanent mark designating the elevation point shall be established on each well. In addition, the ground surface elevation for each well shall be established. Some of the wells will be flush-mounted level with the pavement; thus the land surface elevation will be above the "top of casing" elevation for those wells.

### 5.1.2

Determine the elevation of the directly adjacent ground surface to an accuracy of 0.1 feet.

## 5.2

Delineate the horizontal location of each well from surveyed corners or other features on permanent land monuments in the immediate site area to an accuracy of 0.1 foot, referenced to North American Datum (AND). Baker will supply an existing property plot plan or CADD file for each site to the subcontractor that will serve as the base map for locating surveyed points. All permanent points established during control traverses shall be shown.

## 5.3

Locate various drainage trenches/structures and significant topographic features at Baker's request via the survey. A Baker representative may be present during survey activities to identify points and features to be located. If no Baker representative will be present, the subcontractor will be notified in advance as to what features or types of features are to be included in the survey.

## 5.4

In the absence of facility-established horizontal and vertical control, all survey points will be based on North American Datum (AND) for horizontal control and MSL for vertical control.

## 5.5

The subcontractor shall provide Baker with a letter report containing all relevant survey information along with one legible copy of the field survey notes recorded when determining the surveyed elevations, location of wells, and requested topographic information. The subcontractor shall also provide one reproducible, legible copy of the property map showing the well designation, "top-of-casing" elevation and location at each well, and a table listing the well designation, "top-of-casing" ground surface elevations, coordinates for each well, and plotted horizontal features. Baker cannot verify the accuracy of other site maps. It is recognized that the

subcontractor's responsibility in plotting features is to provide most accurate locations possible on mapping available. Tabulated data provided by the subcontractor, however, must be accurate on an MSL datum specified above. All deliverables must be in ACAD R12.

## 5.6

The subcontractor shall perform these services in accordance with standard, acceptable surveying practices as required by the state in which the work is performed and all work shall be conducted under the supervision of a Registered Land Surveyor, duly licensed to work in the state.

## 6.0 HEALTH AND SAFETY

The subcontractor is to provide for and assume responsibility for adequate health and safety protection for on-site personnel. Baker requires contracted land surveyors to provide evidence of having received OSHA-specified training to conduct work on potentially hazardous sites. The specific content of the training requirements are outlined in 29 CFR 1910.120(e). These requirements include:

- Minimum of 24 hours of hazardous waste training
- Eight hours of additional training for supervisors
- Eight hours of hazardous waste refresher training for every year after the initial 24 hour training
- Medical surveillance as specified in the specific OSHA regulations

At least one of the on-site surveying personnel must have the 32 hour supervisor hazardous waste training. The subcontractor is to provide to Baker personnel on-site or in Baker's offices copies of current training and medical certifications, and to assure that this documentation accompanies their personnel onto the job site.

## 7.0 QUALITY ASSURANCE RECORDS

The Field Logbook shall serve as the quality assurance record for on-site surveying activities.

**APPENDIX O**  
**DRUM SAMPLING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
DRUM SAMPLING**

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**Page 1 of 11  
SOP Number: F110  
Effective Date: 04/94**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE AND APPLICATION</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>METHOD SUMMARY</b>
<b>6.0</b>	<b>INTERFERENCES</b>
<b>7.0</b>	<b>EQUIPMENT APPARATUS</b>
7.1	Bung Wrench
7.2	Drum Deheader
7.3	Backhoe Spike
7.4	Hydraulic Drum Opener
7.5	Pneumatic Devices
7.6	Tube and Spear Device
<b>8.0</b>	<b>PROCEDURES</b>
8.1	Preparation
8.2	Inspection
8.3	Drum Opening
8.4	Drum Sampling
<b>9.0</b>	<b>QUALITY ASSURANCE/QUALITY CONTROL</b>
<b>10.0</b>	<b>REFERENCES</b>

**ATTACHMENT A - DRUM WASTE CHARACTERIZATION SHEET**  
**ATTACHMENT B - FIGURES**

## **DRUM SAMPLING**

### **1.0 PURPOSE**

The purpose of this SOP is intended to provide general information for the sampling of drums by qualified individuals in the field. Due to widely varied (and potentially hazardous) conditions posed by drum sampling, specific SOPs must be determined on a case-by-case basis. This SOP provides information to assist in ensuring that safe procedures are followed as applicable to the inspection, opening, and sampling of drums in the field.

### **2.0 SCOPE AND APPLICATION**

This SOP provides technical guidance on safe and cost-effective response actions at sites containing both known and unknown drum contents. Container contents are sampled and characterized for disposal, bulking, recycling, grouping and/or classification purposes.

### **3.0 DEFINITIONS**

Bung - a threaded metal or plastic plug usually positioned at the top or side of a drum.

Overpack - An external, secondary container used to enclose a packaged hazardous material, hazardous waste, or radioactive waste.

Lab Pack - a drum holding multiple individual containers of laboratory materials normally surrounded by cushioning absorbent material.

### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for selecting qualified individuals for the drum sampling activities.

Project Health and Safety Officer (PHSO) - The PHSO is responsible for developing a site-specific Health and Safety Plan (HASP) for drum sampling activities which include personal protection levels, air monitoring requirements, and safe drum sampling procedures.

Site Health and Safety Officer (SHSO) - The SHSO is responsible for ensuring that the proper respiratory and personal protective equipment for each member of the sampling team is selected in compliance with the HASP, and coordinating these efforts with the Field Team Leader.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the drum sampling techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing drum sampling activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project-specific procedures as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all sampling data on the appropriate Drum Sample Characterization Sheet presented as Attachment A and in the Field Logbook.

## **5.0 METHOD SUMMARY**

Prior to sampling, drums should be inventoried and properly staged in a secure area. An inventory entails recording visual qualities of each drum and any characteristics pertinent to the contents' classification. Staging involves the organization and sometimes consolidation of drums which have similar wastes or characteristics.

## **6.0 INTERFERENCES**

The practice of tapping drums to determine their contents is neither safe nor effective and should not be used if the drums are visually over pressurized (bulging) or if shock-sensitive materials are suspected. Drums that have been over pressurized, to the extent that the head is swollen several inches above the chime (beveled edge of drumtop), should not be moved. A number of devices have been developed for venting swollen drums. These devices are described in Section 7.0.

## **7.0 EQUIPMENT APPARATUS**

The following are standard materials and equipment required for drum sampling:

- Health and Safety Plan
- Air monitoring equipment
- Fire extinguishing equipment
- Personal protective equipment
- Wide mouth glass jars with teflon cap liner, approximately 500 ml volume
- Uniquely numbered sample identification labels with corresponding data sheets
- One-gallon covered (paint) cans half-filled with absorbent (i.e. kitty litter or vermiculite)
- Chain-of-Custody forms
- Decontamination plan and materials
- Glass thieving tubes or Composite Liquid Waste Sampler (COLIWASA)
- Drum opening devices

### **7.1 Bung Wrench**

A common method for opening drums manually is using a universal bung wrench (Figure 1, Attachment B). These wrenches have fittings made to remove nearly all commonly encountered bungs. They are usually constructed of cast-iron, brass or a bronze-beryllium, nonsparking alloy formulated to reduce the likelihood of sparks. The use of a "NONSPARKING" wrench does not completely eliminate the possibility of a spark being produced, therefore extreme caution should be exercised.

## **7.2 Drum Deheader**

One means by which a drum can be opened manually (when a bung is not removable with a bung wrench) is by using a drum deheader (Figure 2, Attachment B). This tool is designed to cut the lid of a drum off (or part way off) by means of a scissors-like cutting action. This device is limited in that it can be attached only to closed head drums. Drums with removable heads must be opened by other means.

## **7.3 Backhoe Spike**

The most common means used to open drums remotely for sampling is the use of a metal spike attached or welded to a backhoe bucket (Figure 3, Attachment B). In addition to being very efficient, this method can greatly reduce the likelihood of personnel exposure to the potentially hazardous nature of the drum's contents.

## **7.4 Hydraulic Drum Opener**

Another remote drum opening procedure is the utilization of remotely operated hydraulic devices. One such device uses hydraulic pressure to pierce through the wall of a drum (Figure 4, Attachment B). The device consists of a manually operated pump which pressurizes oil through a length of hydraulic line.

## **7.5 Pneumatic Devices**

A pneumatic bung remover consists of a compressed air supply that is controlled by a heavy-duty, two-stage regulator. A high pressure air line of desired length delivers compressed air to a pneumatic drill, which is adapted to turn a bung fitting selected to fit the bung to be removed (Figure 5, Attachment B). It should be noted that this bung removal method does not permit the slow venting of the container, and therefore appropriate precautions must be taken to reduce personnel exposure to pressurized, potentially hazardous drum contents. It also requires the container to be upright and relatively level. Bungs that are rusted shut or are in very poor condition cannot be removed with this device.

## **7.6 Tube and Spear Device**

A tube and spear device is a hollow tube with a rod positioned inside the tube so that the tube acts as a guide and safety shield and the rod, which is pointed at the impact end, acts as a puncturing tool. The tube, generally a light aluminum tube (3 meters long), is positioned at the vapor space of the drum. A rigid hooking device attached to the tube goes over the chime and holds the spear securely in place. The spear is inserted in the tube and positioned against the drum wall. A sharp blow on the end of the spear drives the sharpened tip through the drum and the gas vents along the grooves. The device can be inexpensively and easily designed and constructed where needed. Once the pressure has been relieved, the bung can be removed and the drum contents sampled. For safety reasons, this device shall be operated remotely.

## **8.0 PROCEDURES**

It is anticipated that the procedures for drum sampling may include a limited degree of drum handling. Therefore, it will be necessary to inspect the drum(s) for certain conditions prior to sampling.

## 8.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies will be needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or preclean equipment, and ensure that the equipment is in good working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan.
6. Use marking devices to identify and mark all sampling locations. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions.

## 8.2 Inspection

Prior to sampling, drums will be visually inspected to gain as much information as possible about their contents. Items to consider during inspection include:

- Symbols, wording, labels, or other marks indicating that drum contents are hazardous, e.g., radioactive, explosive, corrosive, toxic, or flammable.
- Symbols, wording, labels, or other marks indicating that the drum contains discarded laboratory chemicals, reagents, or other potentially dangerous materials in small-volume individual containers.
- Signs of deterioration such as corrosion, rust, and leaks.
- Signs of the chemical nature of the contents, such as residue, crystal buildup, etc. at bung opening.
- Signs that the drum is under pressure such as swelling and bulging.
- Special drum types (refer to Table 1).
- Configuration of the drumhead (ringtop or bung).
- Orientation such as whether the drum is standing upright, tilted, or lying on its side.
- Accessibility of the drum.



Monitoring will be conducted around the drums using instruments such as a gamma radiation survey instrument, organic vapor monitor (OVA or HNu), colorimetric tubes (Dräger tubes), and/or a combustible gas meter. The results can be used to classify the drums into categories such as radioactive, leaking/deteriorating, bulging, explosive/shock-sensitive, or laboratory packs.

**Personnel will not handle, move, open, sample or in anyway disturb a drum containing radioactive waste, explosive or shock-sensitive waste, laboratory packs, or biohazardous waste until specific direction and safe procedures are received from the Project Manager, PHSO and the Field Team Leader.**

When drums exhibit the characteristics of the aforementioned categories, the following procedures will be followed:

- Radioactive Wastes - If the drum exhibits radiation levels above background, normally 0.01-0.02 mrem/hr (millirem equivalent in man per hour), that are less than or equal to 2 mrem/hr, there is a possible radiation source present. Continue the investigation with caution, and inform the SHSO. If the radiation levels are greater than 2 mrem/hr there is a potential radiation hazard. Work will stop, and the Field Team Leader and Project Manager will be notified so that new procedures can be developed and implemented.
- Explosive or Shock-Sensitive Waste - If handling is necessary, exercise extreme caution, have nonessential personnel move to a safe distance, and use a grapppler unit for initial handling which is constructed for explosive containment. Use nonsparking equipment and/or remote control devices.
- Bulging Drums - Do not move drums under internal pressure unless proper equipment is used, such as a grapppler unit constructed for explosive containment.
- Packaged Laboratory Wastes (Lab Packs) - Lab Packs can be an ignition source for fires and sometimes contain shock-sensitive materials. Once a lab pack has been opened, a chemist or other qualified individual should visually inspect, classify and segregate the bottles, according to the hazards of the wastes. The objective of such a classification system is to ensure safe segregation of the lab packs' contents (refer to Table 2 for an example of a lab pack classification). If crystalline material is noted at the neck of any bottle, handle it as a shock-sensitive waste (due to the potential presence of picric acid, potassium permanganate or explosive mixtures resulting when the aqueous solution crystallizes), or other inimical (harmful) materials, and obtain advice from qualified personnel prior to handling.

Until drum contents are characterized, sampling personnel will assume that unlabeled drums contain hazardous materials. Personnel also should be aware that drums are frequently mislabeled and may not contain the material identified.

### 8.3 Drum Opening

Drums are to be opened and sampled in place. For opening drums manually, equipment such as a nonsparking metal (brass, bronze/manganese, aluminum, molybdenum) bung/plug wrench and a drum deheading device will be used for waste contents that are known to be nonreactive and nonexplosive, within a structurally sound drum. The drums will be grounded prior to opening either the bung or the lid

While opening drums manually with a bung wrench, the following procedures will be used:

- Drums will be positioned bung up, or, for drums with bungs on the side, laid on their sides with the bung plug up. Note that care should be taken when moving a drum into position for opening.
- Use a wrenching motion that is a slow and steady pull across the drum, using a "cheater bar" if the leverage for unscrewing the bung is poor.
- If there is evidence of incompatible chemical reactions, a sudden pressure buildup, or a release of potentially toxic fumes while the bung is being loosened, field personnel will immediately leave the area and arrange for remote drum opening equipment to be used.
- If the drum cannot be opened successfully using a nonsparking hand wrench, then other methods of drum opening (deheading or puncturing) must be considered. If deheading or puncturing a drum, it will be necessary to overpack the drum to minimize the potential for spilling the drum's contents.
- If the drum shows signs of swelling or bulging, perform all steps slowly. From a remote location, relieve excess pressure prior to drum opening using the devices listed below, if possible. If performing drum opening activities manually, place a barrier such as an explosion-resistant plastic shield between the worker and bung to deflect any gas, liquid, or solids which may be expelled as the bung is loosened.

Whenever possible, use the following remote-controlled devices for opening drums:

- A pneumatically operated impact wrench to remove drum bungs.
- A hydraulically or pneumatically operated drum piercer.
- A backhoe equipped with bronze spikes for penetrating drum tops (typical in large-scale operations).

Additional general procedures for drum opening are as follows:

- If a supplied-air respiratory protection system is used, the bank of air cylinders must be maintained outside of the work area.

- If personnel must be located near the drums being opened, place explosion-resistant plastic shields between them and the drums, in case of detonation. Locate controls for drum opening equipment, monitoring equipment, and fire suppression equipment behind the explosion-resistant plastic shield. Nonessential personnel must be positioned upwind from the drum opening and sampling operations.
- When feasible, monitor air quality continuously during drum opening, and as close as possible to the potential source of contaminants, (i.e., placing probes as close as practical without hindering drum opening operations), and hang or balance the drum opening equipment to minimize exertion.
- Do not use picks, chisels, etc. to open drums manually.
- Open exotic metal drums and polyethylene or polyvinylchloride-lined (PVC-lined) drums by removing or manually drilling the bung, while exercising extreme caution.
- Do not open or sample individual containers within laboratory packs.
- Reseal open bungs and/or drill openings as soon as possible, with new bungs or plugs to avoid explosions and/or vapor generation. If an open drum cannot be resealed, place the drum into an overpack.
- Plug any openings in pressurized drums with pressure venting caps set to a 5-psi release to allow venting of vapor pressure.
- Decontaminate and/or properly dispose of sampling equipment after each use to avoid mixing incompatible wastes and contaminating subsequent samples.

#### 8.4 **Drum Sampling**

When sampling a previously sealed vessel, check for the presence of bottom sludge. Since some layering or stratification is likely in any solution left undisturbed over time, take a sample that represents the entire depth of the vessel.

The most widely used instrument for sampling is a glass tube commonly referred to as a glass thief (Figure 6, Attachment B). This tool is simple, cost effective, quick and collects a sample without having to decontaminate. Glass thieves are typically 6 mm to 16 mm I.D. and 48 inches long.

Drum sampling can be a very hazardous activity because it often involves direct contact with unidentified wastes. Prior to collecting any sample, field team personnel will become familiar with the procedures identified in the Sampling Plan and in this SOP.

Certain information can be construed from the drumhead configuration prior to sampling, such as:

- Removable "Whole" Lid = designed to contain solid material
- Bung opening = designed to contain liquids
- Drum Liner = may contain a highly corrosive or otherwise hazardous material

When manually sampling from a drum, use the following techniques:

- Keep sampling personnel at a safe distance while drums are being opened. Sample only after opening procedures are complete.
- Do not lean over or between other drums to reach the drum being sampled.
- Cover drum tops with plastic sheeting or other suitable uncontaminated materials to avoid excessive contact with the drum tops.
- Never stand on drums. Use mobile steps or another platform to achieve the height necessary to safely sample from the drums.
- After the drum has been opened, monitor headspace gases with no less than an explosimeter and an organic vapor analyzer. In most cases it is impossible to observe the contents of these sealed or partially sealed vessels.
- Obtain samples with either glass rods (thiefs) or with a vacuum pump and tubing. Do not use contaminated items such as discarded rags during sampling. Glass rods will be removed prior to pumping to minimize damage to pumps.
- Identify each drum with a sample number. Record the number on the Drum Waste Characterization Sheet and permanently on the drum (mark lid and side) using either a label, permanent marker, or spray paint. Cover drums with plastic sheeting and secure to minimize degradation of labeling from variable weather conditions.

#### **8.4.1 Procedures for using a glass thief are as follows:**

1. Remove cover from sample container.
2. Insert glass tubing almost to the bottom of the drum or until a solid layer is encountered. About one foot of tubing should extend above the drum.
3. Allow the waste in the drum to reach its natural level in the tube.
4. Cap the top of the sampling tube with a tapered stopper or thumb, ensuring liquid does not come into contact with stopper.
5. Carefully remove the capped tube from the drum and insert the uncapped end in the sample container.

6. Release stopper and allow the glass thief to drain until the container is approximately 2/3 full.
7. Remove tube from the sample container.
8. Cap the sample container tightly and place prelabeled sample container in a carrier.
9. Replace bung or lid securely on drum.
10. Break the thief into pieces inside a drum which has been designated for solid hazardous waste disposal. Previously, drum thieves were broken and disposed inside the drum being sampled. However, this activity hindered the future disposal of liquid drum contents by introducing solid material.
11. Log all samples in the site logbook and on field data sheets.
12. Package samples and complete necessary paperwork.
13. Transport sample to decontamination zone in preparation for transport to analytical laboratory.

#### **8.4.2 COLIWASA Sampler**

The Composite Liquid Waste Sampler (COLIWASA) is designed to collect a sample from the full depth of a drum and maintain it in the transfer tube until delivery to the sample bottle. The COLIWASA (Figure 7, Attachment B) is a much cited sampler designed to permit representative sampling of multiphase wastes from drums and other containerized materials. One configuration consists of a 152 cm x 4 cm inside diameter (I.D.) section of tubing with a neoprene stopper at one end attached by a rod running the length of the tube to a locking mechanism at the other end. Manipulation of the locking mechanism opens and closes the sampler by raising and lowering the neoprene stopper.

### **9.0 QUALITY ASSURANCE/QUALITY CONTROL**

The following quality assurance procedures apply:

- Document all data on standard chain of custody forms, field data sheets and/or within site logbooks.
- Operate all instrumentation in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the Work Plan and Sampling Plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and must be documented in the field logbook.

Quality assurance records shall consist of completed Drum Waste Characterization Sheets and data entered into the Field Logbook. A sample Drum Waste Characterization Sheet is presented as Attachment A. Attachment B contains example figures of drum sampling equipment.

## 10.0 REFERENCES

Stevenson, H. L., and B. Wyman, 1991. The Facts on File Dictionary of Environmental Science. Maple-Vail Book Manufacturing Group.

NIOSH/OSHA/USCG/EPA, 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. Publication No. 85-115.

U.S. EPA, 1986. Drum Handling Practices at Hazardous Waste Sites. Wetzel, Furman, Wickline, and Hodge, JRB Associates, McLean, Virginia. Publication No. 86-165362.

NIOSH, 1990. NIOSH Pocket Guide to Chemical Hazards. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio. Publication No. 90-117.

U.S. EPA, 1991 Compendium of ERT Waste Sampling Procedures. OSWER Directive 9360.4-07. EPA/540/P-91/008

**ATTACHMENT A**

**DRUM WASTE CHARACTERIZATION SHEET**

**Baker**

Baker Environmental, Inc.

Drum/Sample No. \_\_\_\_\_

Project Location \_\_\_\_\_ Project No. \_\_\_\_\_

Project Manager \_\_\_\_\_ Telephone \_\_\_\_\_

Logger \_\_\_\_\_ Sampler \_\_\_\_\_

Weather \_\_\_\_\_ Date \_\_\_\_\_ Time \_\_\_\_\_

Drum Type: ☐ Fiber ☐ Steel ☐ Poly ☐ Stainless Steel ☐ Nickel  
☐ Poly-Lined ☐ Ring Top ☐ Closed Top ☐ Overpacked

Drum Size: 85 ☐ 55 ☐ 42 ☐ 30 ☐ 16 ☐ 10 ☐ 5 ☐ Other \_\_\_\_\_Drum Contents: Amount Full ☐ 3/4 ☐ 1/2 ☐ 1/4 ☐ <1/4 ☐ MT ☐Drum Condition: Good ☐ Fair ☐ Poor ☐

Physical State					Color	Clarity			Layer Thickness (Inches)
	Liquid	Solid	Gel	Sludge	Use Std. Colors	Clear	Cloudy	Opaque	
Top									
Middle									
Bottom									

pH \_\_\_\_\_ PID \_\_\_\_\_ ppm

Rad Meter \_\_\_\_\_ mr/hr

Other \_\_\_\_\_

MFG Name \_\_\_\_\_

Chemical Name \_\_\_\_\_

Additional Information: \_\_\_\_\_

**LABORATORY COMPATIBILITY ANALYSES**

Physical State					Color	Clarity			Water Sol.	React.	pH	Hex. Sol.	Per.	Oxid.	CN	Sul.	Biel-Stein	Flash Point
	Liquid	Solid	Gel	Sludge	Use Std. Colors	Clear	Cloudy	Opaque	Sol. S or I Density	A - Air W - Water	Std. Unit	S or I	+ or -	+ or -	+ or -	+ or -	+ or -	°C or °F
Top																		
Middle																		
Bottom																		

Comments: \_\_\_\_\_

PCB Conc. \_\_\_\_\_ ppm Flash Point \_\_\_\_\_ °C

Data Reviewer \_\_\_\_\_ Compatibility Comp. Bulk No. \_\_\_\_\_

Field Reviewer \_\_\_\_\_



**ATTACHMENT B**

**FIGURES**

Figure 1: Universal Bung Wrench

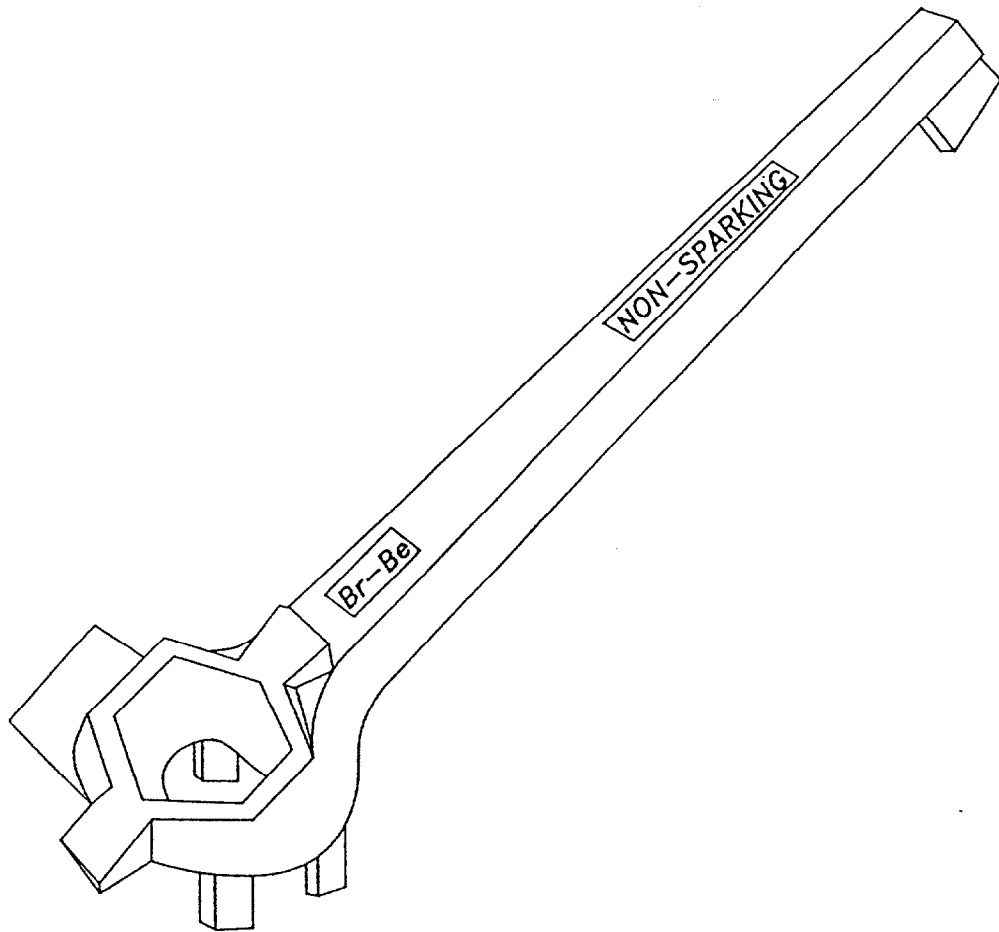


Figure 2: Drum Deheader

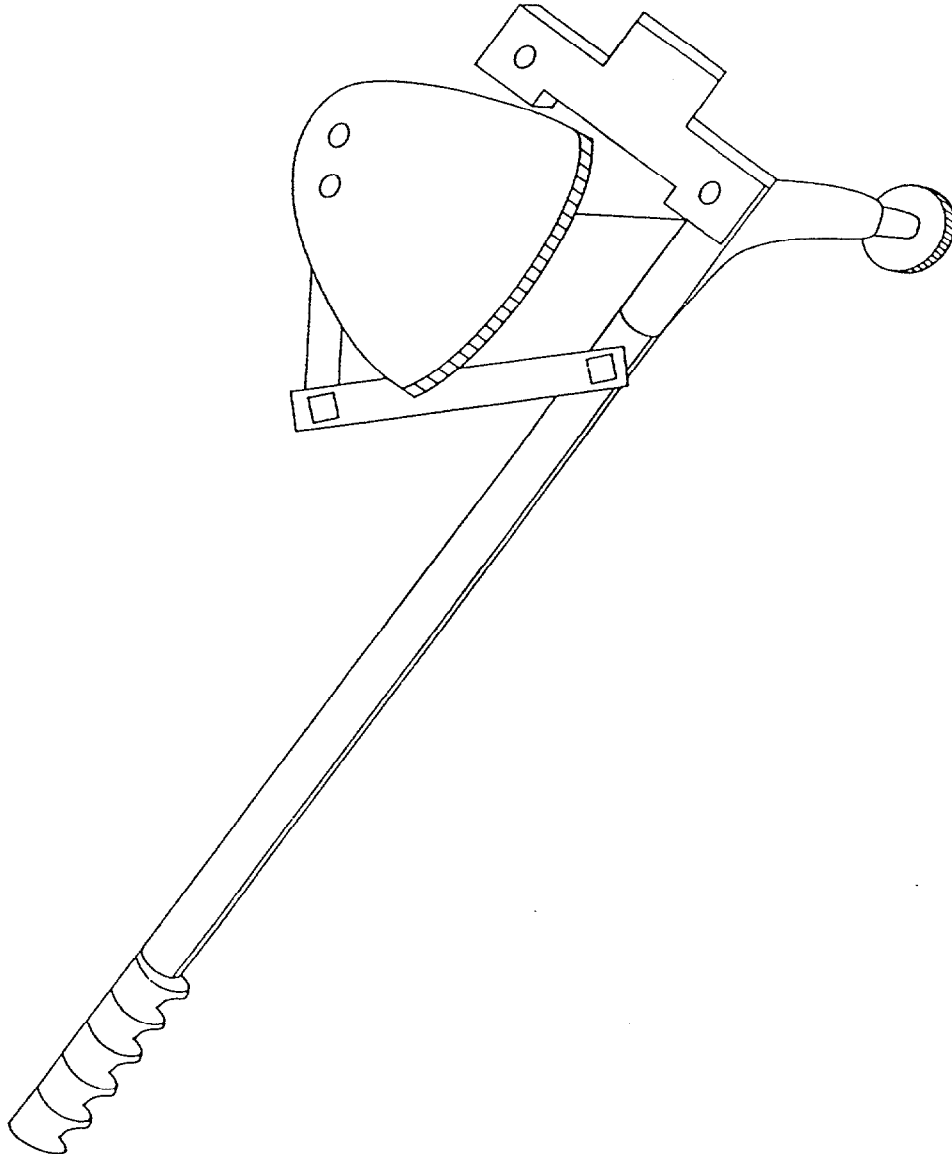


Figure 3: Hand Pick, Pickaxe, and Hand Spike

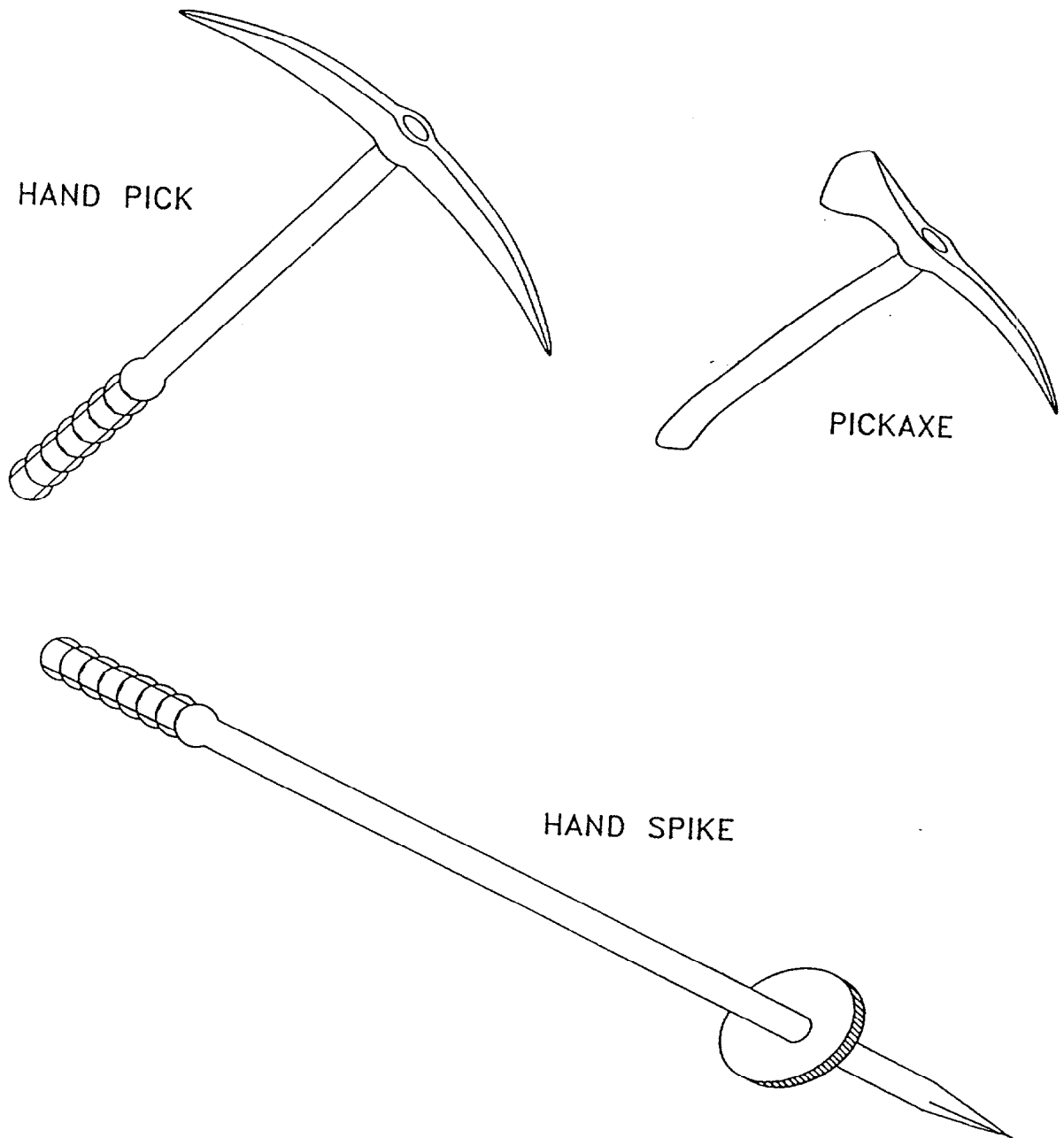


Figure 4: Backhoe Spike

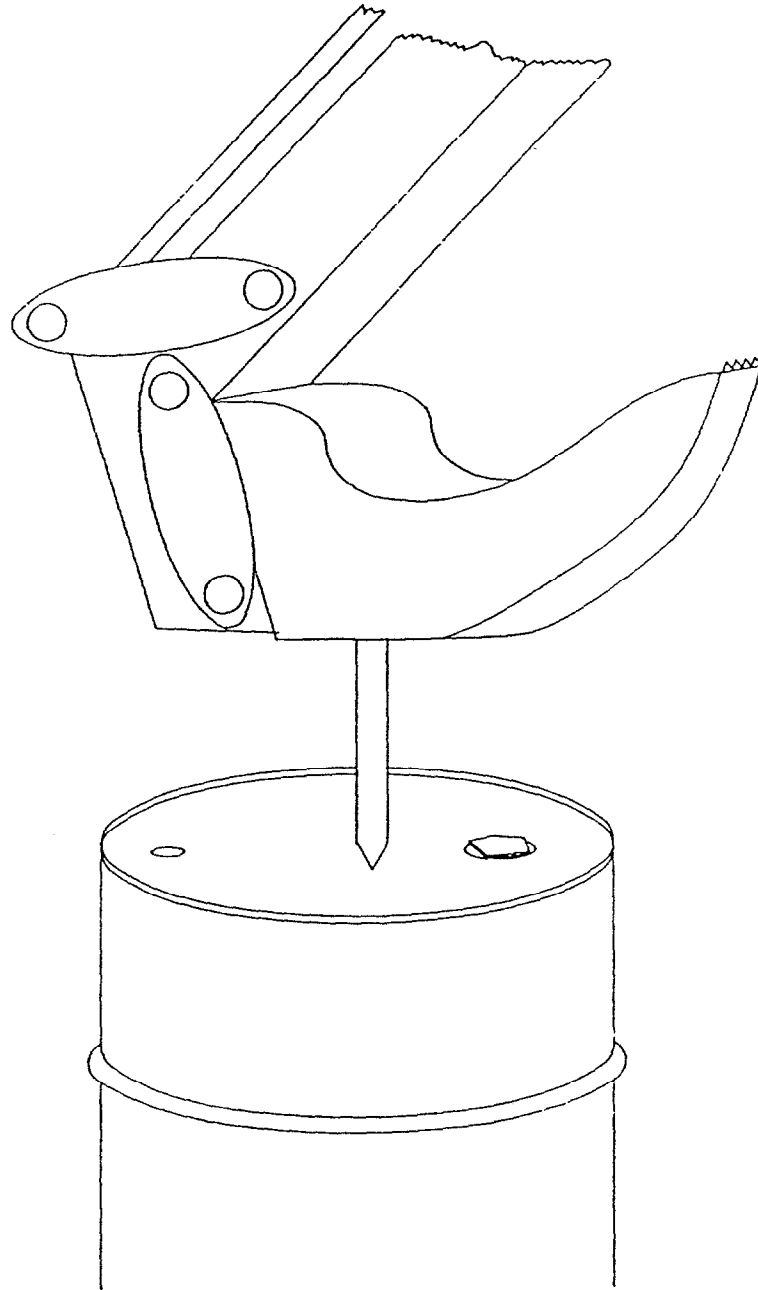


Figure 5: Hydraulic Drum Opener

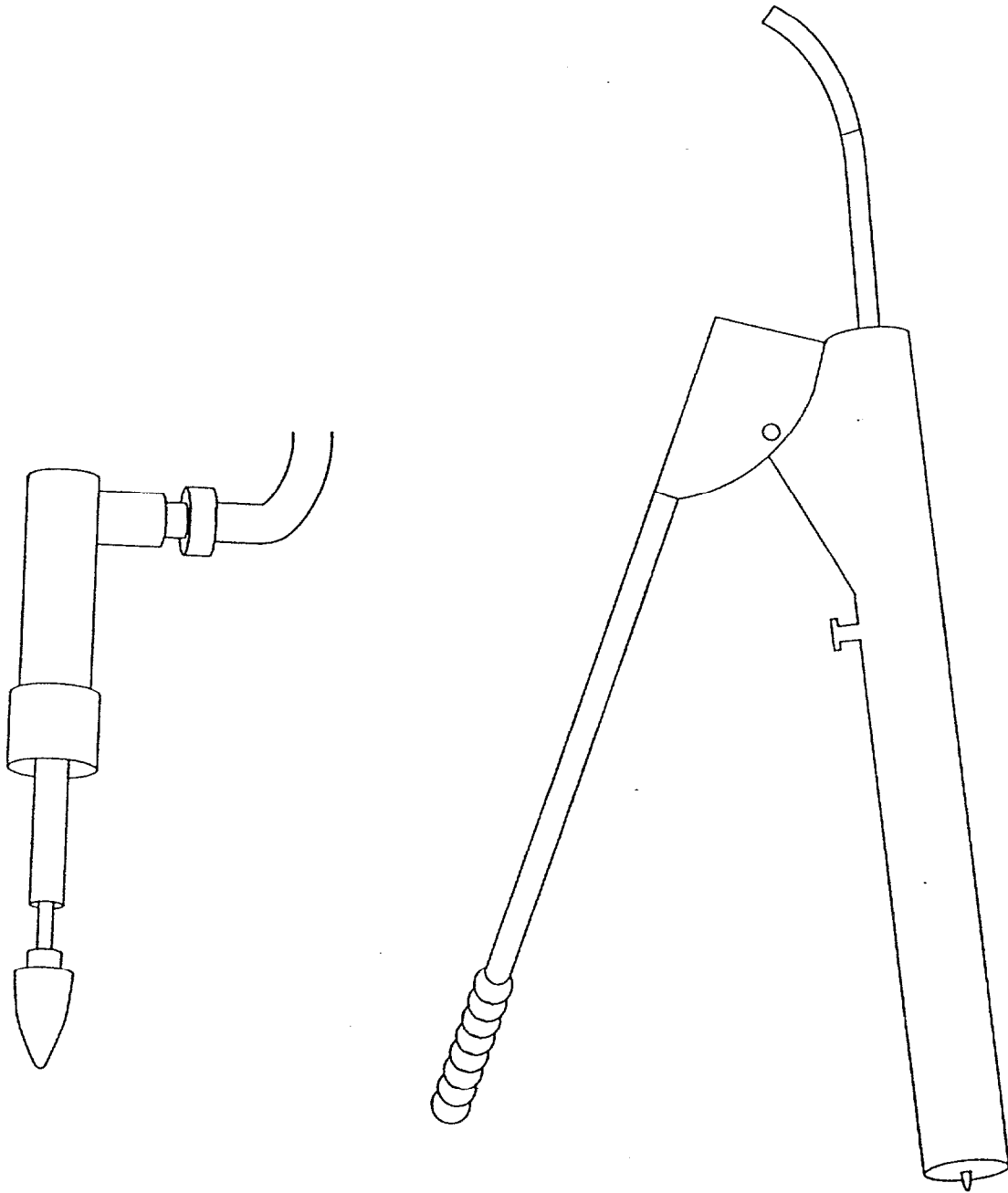


Figure 6: Pneumatic Bung Remover

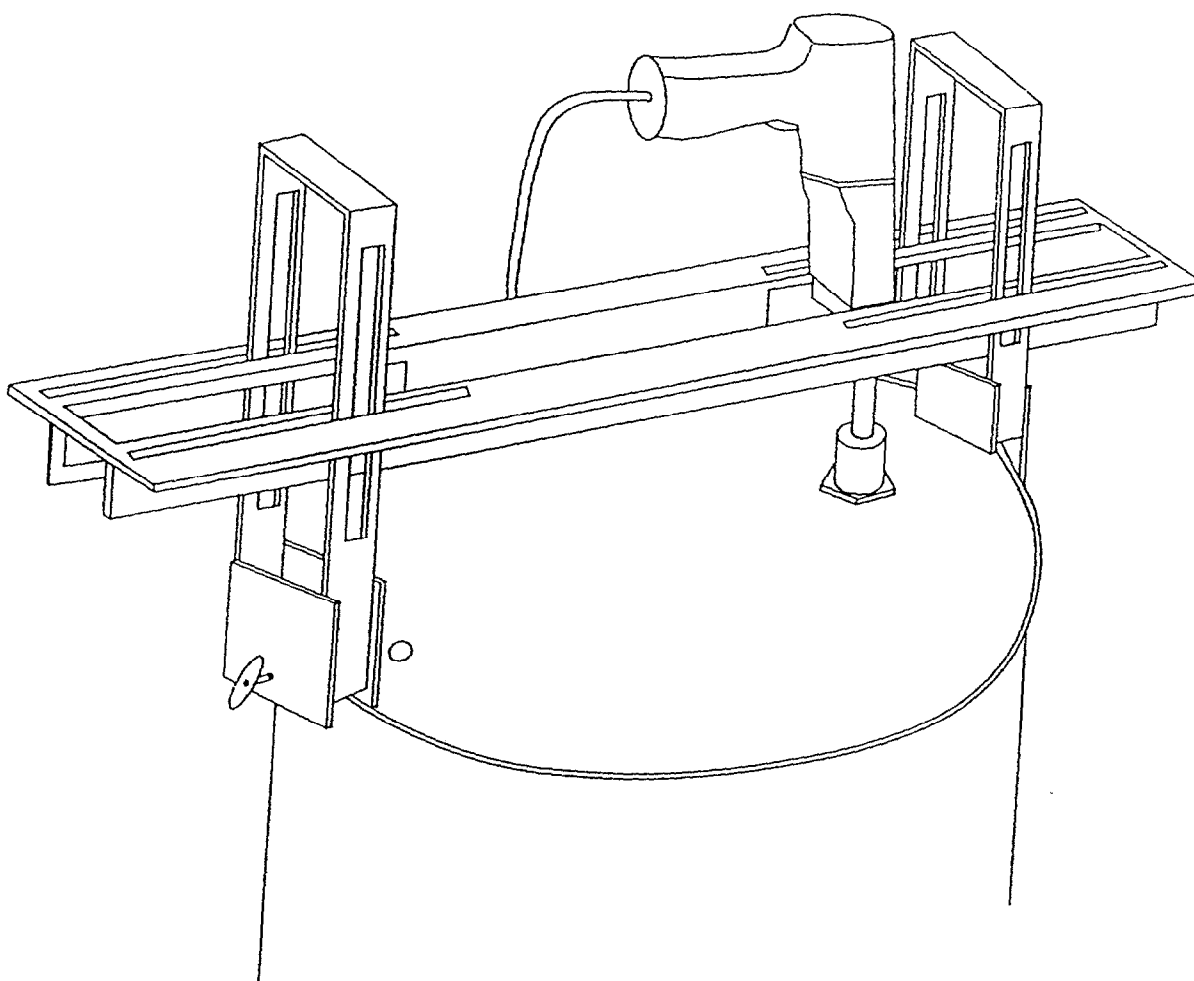
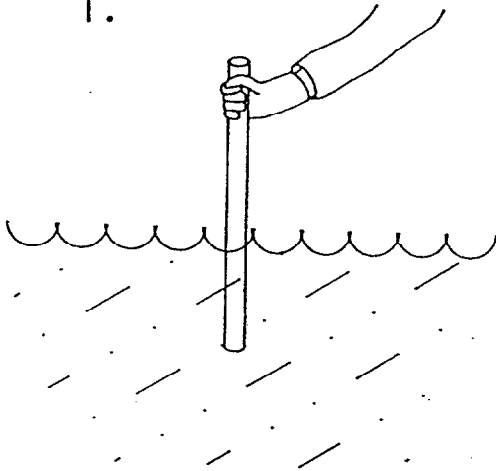


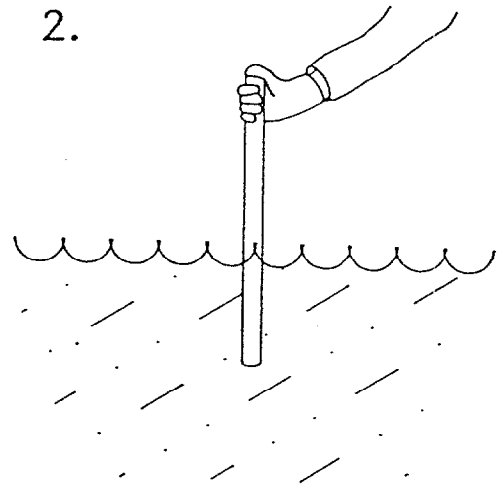
Figure 7: Glass Thief

1.



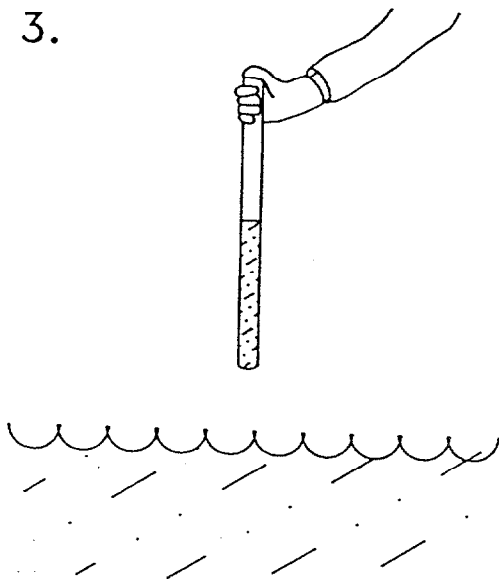
Insert open tube (thief) sampler in containerized liquid.

2.



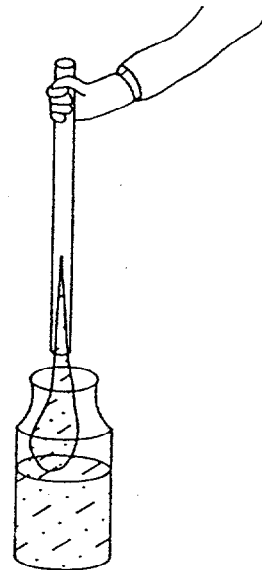
Cover top of sampler with gloved thumb.

3.



Remove open tube (thief) sampler from containerized liquid.

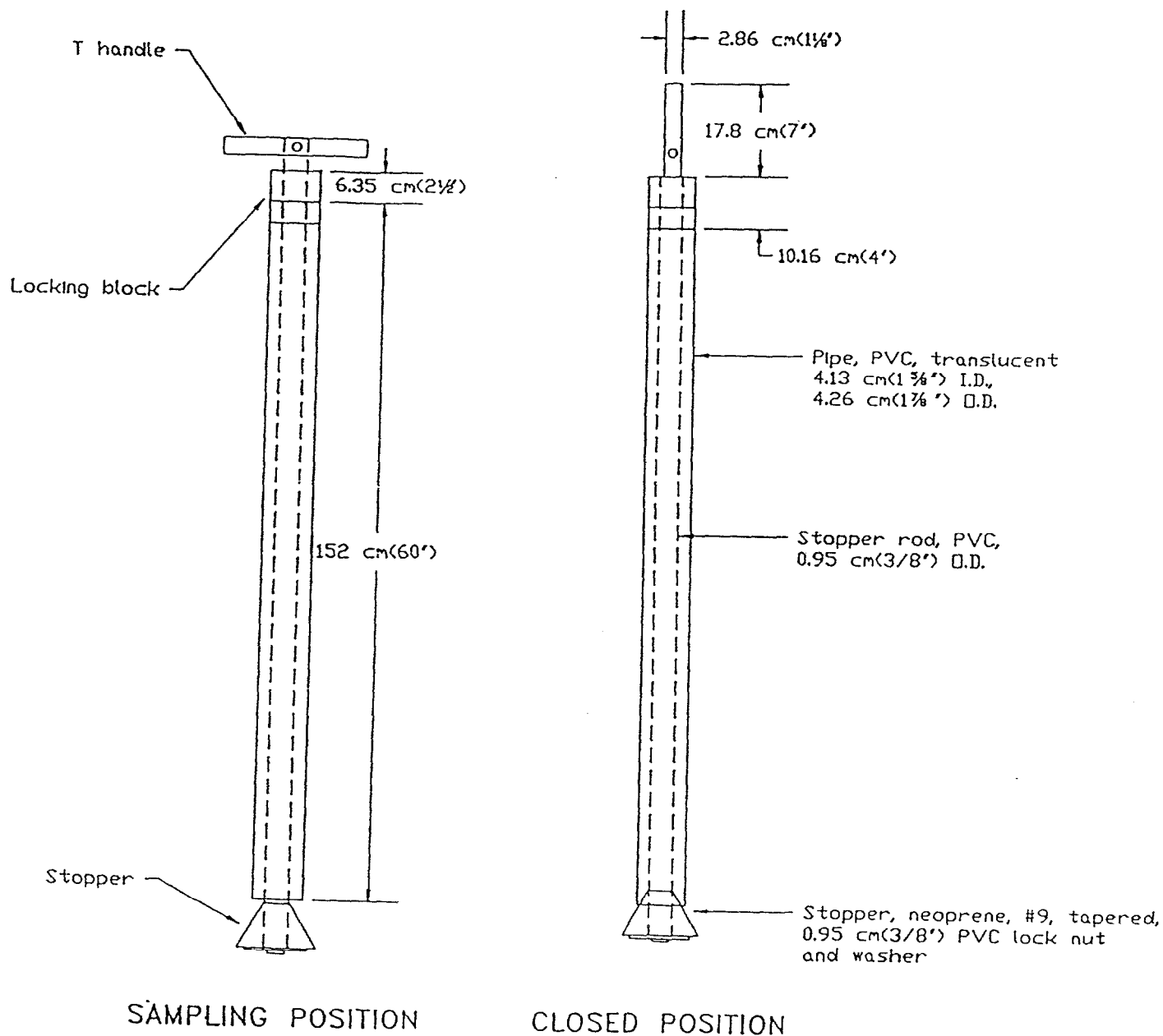
4.



Place open tube sampler over appropriate sample bottle and remove gloved thumb.



Figure 8: COLIWASA



**APPENDIX P**  
**WASTEWATER SAMPLE ACQUISITION**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
WASTEWATER SAMPLE ACQUISITION**

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**Page 1 of 4  
SOP Number: F109  
Effective Date: 04/94**

**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	On-Shore
5.2	Off-Shore
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## WASTEWATER SAMPLE ACQUISITION

### 1.0 PURPOSE

The purpose of this SOP is to provide general reference information for collecting wastewater samples.

### 2.0 SCOPE

This procedure provides information for the acquisition of waste water samples. Review of the information contained herein will ensure that sample acquisition is properly conducted.

### 3.0 DEFINITIONS

Sampling Plan - A "plan of action" that guides the implementation of methods that will lead to achieving the plans objective(s).

Grab Sample - An entire sample which is collected at one specific sample location at a specific point in time.

Composite Sample - A sample which is collected at several different locations and/or at different points in time.

Environmental Sample - Samples of naturally occurring materials; soil, sediment, air, water.

Waste Sample - Samples which are comprised of process wastes or other manmade waste material(s).

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project specific plans are in accordance with procedures where applicable, or that other approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein.

Field Team Leader - The Field Team Leader is responsible for selecting and detailing the waste water sample acquisition techniques and equipment to be used. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that the Field Investigation personnel performing the sample acquisition activities have been briefed and trained to execute these procedures.

Field Investigation Personnel - It is the responsibility of the Field Investigation Personnel to follow these procedures or to follow documented project specific procedures as outlined in the Work Plan and as directed by the Field Team Leader and Project Manager. The Field Investigation Personnel are responsible for documenting all wastewater sampling activities and ambient air monitoring results in the field log book.

### 5.0 PROCEDURES

This protocol outlines procedures and equipment for the collection of representative liquid samples and sediment/sludge samples from standing lakes, ponds and lagoons, and flowing streams, rivers, channels, sewers and leachate seeps.

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine (e.g., collecting a surface water sample from a two foot deep stream). Other times, the nature of site specific conditions may dictate that: 1) special equipment is needed to access the sample, 2) appropriate health and safety measures are critical, 3) proper timing is essential due to waste release times or tidal fluctuations, and/or 4) wastewater flow rate is a factor for consideration.

Prior to sample collection, impoundment characteristics (size, depth, flow) should be recorded in the field log book. Sampling should proceed from downstream locations to upstream locations so that sediment disturbance (turbidity) caused by sampling does not affect sample quality. Additionally, if a sediment sample will be collected at the same location as a liquid sample, the liquid sample must be collected first to minimize sample turbidity.

If the Sampling Plan requires that samples are to be collected from the shore of an impoundment, specific health and safety considerations must be addressed. The person collecting the sample should be fitted with a safety harness and rope secured to a sturdy, immobile object on shore. Backup personnel should be available to assist in sample collection and should be prepared and able to pull the sampler to safety if unstable banks are encountered.

To more adequately characterize the content and/or quality of an impoundment, samples may be collected away from the shoreline, often at various depths. If the content of the impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. If a barge or boat is used, each person on the vessel must be equipped with a life preserver and/or lifeline.

The sampling of liquids in lakes, ponds, lagoons, streams, rivers, channels, sewers and leachate seeps is generally accomplished through the use of one of the following samplers:

- Laboratory cleaned sample bottle
- Pond sampler
- Weighted bottle sampler
- Wheaton dip sampler
- Kemmerer Depth Sampler
- Bacon Bomb Sampler

The factors that will contribute to the selection of a sampler include the width, depth and flow of the location being sampled, and whether the sample will be collected from the shore or a vessel.

For flowing liquids, tidal influence on the collected sample is an additional concern and should be addressed in the Sampling Plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages as well as seasonally. Tidal information can be obtained from local bait shops, newspaper listings and/or local radio or television news reports.

Samplers may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and streams it may be nearly impossible to collect a mid-channel sample at a specific point. Low flowing streams and leachate seeps present the opposite problem. In these cases the sampler should attempt to locate an area where flow is obstructed and a pool is created. If this is not possible, sediment may be dug with a decontaminated trowel to create a pooled area where sufficient liquid will accumulate for sampling.

## 5.1 On-Shore

If the banks are not sloped, sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where access is limited, a pond sampler, by virtue of its extension capabilities, may be necessary. For a stream, channel or river, collect the sample at mid-depth. For standing liquid, collect the sample from just below the surface or at mid-depth. Once the sample is obtained by sample vessel, transfer it directly into the sample bottle. If volatile organic compounds (VOCs) are to be analyzed, fill the appropriate sample containers for VOCs first, then fill sample containers for other chemical analyses. Decontaminate the sampling device following procedures outlined in the Sampling Plan and/or SOP F502 before obtaining the next sample.

## 5.2 Off-Shore

Collect a liquid sample using the sample bottle or decontaminated pond sampler, if necessary. If the liquid has stratified, a sample of each strata should be collected. One of the depth samplers listed above will allow collection of discrete representative liquid samples at various depths. Proper use of the chosen sampling device includes slowly lowering and careful retrieval of the sample, immediate transfer of the liquid into the appropriate sampling container, and logbook notation of the depth at which the sample was collected. After collection, the sampling device must be decontaminated prior to obtaining the next sample.

## 6.0 QUALITY ASSURANCE RECORDS

Quality assurance records shall consist of recording sample date and acquisition time(s), sample number, sample location(s), sample depth(s), name of the Field Investigation Personnel collecting the sample(s), and Service Order Number in the field logbook. The type of container used to hold the sample and preservative agent, if needed, also will be documented, as will the method of sampling equipment decontamination. In addition, if photographs are taken of the sample site, the photograph number and direction of view shall be recorded as well.

## 7.0 REFERENCES

Field Sampling Procedures Manual. Chapter 8. New Jersey Department of Environmental Protection and Energy, Trenton, New Jersey. May 1992.

Sampling and Analysis Methods. Compilation of EPA's Sampling and Analysis Methods, USEPA, Washington, D.C. 1991.

Characterization of Hazardous Waste Sites. USEPA, Washington, D. C. 1990.



**APPENDIX Q**  
**SAMPLE PRESERVATION AND HANDLING**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
SAMPLE PRESERVATION AND HANDLING**

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**Page 1 of 5  
SOP Number: F301  
Effective Date: 04/94**

**TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sample Containers
  - 5.2 Preservation Techniques
  - 5.3 Sample Holding Times
- 6.0 SAMPLE HANDLING AND TRANSPORTATION**
- 7.0 REFERENCES**

**ATTACHMENT A -- REQUIRED CONTAINER, PRESERVATION TECHNIQUES, AND  
HOLDING TIMES**

**ATTACHMENT B -- SAMPLE SHIPPING PROCEDURES**



## **SAMPLE PRESERVATION AND HANDLING**

### **1.0 PURPOSE**

This SOP describes the appropriate containers for samples of particular matrices, and the steps necessary to preserve those samples when shipped off site for chemical analysis. It also identifies the qualifications for individuals responsible for the transportation of hazardous materials and samples and the regulations set forth by the Department of Transportation regarding the same.

### **2.0 SCOPE**

Some chemicals react with sample containers made of certain materials; for example, trace metals adsorb more strongly to glass than to plastic, while many organic chemicals may dissolve various types of plastic containers. It is therefore critical to select the correct container in order to maintain the integrity of the sample prior to analysis.

Many water and soil samples are unstable and may change in chemical character during shipment. Therefore, preservation of the sample may be necessary when the time interval between field collection and laboratory analysis is long enough to produce changes in either the concentration or the physical condition of the constituent(s). While complete and irreversible preservation of samples is not possible, preservation does retard the chemical and biological changes that may occur after the sample is collected.

Preservation techniques are usually limited to pH control, chemical addition(s), and refrigeration/freezing. Their purposes are to (1) retard biological activity, (2) retard hydrolysis of chemical compounds/complexes, (3) reduce constituent volatility, and (4) reduce adsorption effects.

Typical sample container and preservation requirements for this project are provided in Attachment A of this SOP. Note that sample container requirements (i.e., volumes) may vary by laboratory.

The Department of Transportation, Code of Federal Regulations (CFR) Title 49 establishes regulations for all materials offered for transportation. The transportation of environmental samples for analysis is regulated by Code of Federal Regulations Title 40 (Protection of the Environment), along with 49 CFR Part 172 Subpart H. The transportation of chemicals used as preservatives and samples identified as hazardous (as defined by 49 CFR Part 171.8) are regulated by 49 CFR Part 172.

### **3.0 DEFINITIONS**

HCl - Hydrochloric Acid

H<sub>2</sub>SO<sub>4</sub>- Sulfuric Acid

HNO<sub>3</sub> - Nitric Acid

NaOH - Sodium Hydroxide

Normality (N) - Concentration of a solution expressed as equivalents per liter, where an equivalent is the amount of a substance containing one mole of replaceable hydrogen or its equivalent. Thus, a one molar solution of HCl, containing one mole of H, is "one-normal," while a one molar solution of H<sub>2</sub>SO<sub>4</sub> containing two moles of H, is "two-normal."

#### **4.0 RESPONSIBILITIES**

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is also responsible for proper certification of individuals responsible for transportation of samples of hazardous substances.

Field Team Leader - It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures. The Field Team Leader is responsible to ensure all samples and/or hazardous substances are properly identified, labeled, and packaged prior to transportation.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate sample preservation and handling. It is also the responsibility of the field sampling personnel to understand and adhere to the requirements for proper transportation of samples and/or hazardous substances.

#### **5.0 PROCEDURES**

The following procedures discuss sample containerization and preservation techniques that are to be followed when collecting environmental samples for laboratory analysis.

##### **5.1 Sample Containers**

For most samples and analytical parameters either glass or plastic containers are satisfactory. In general, if the analyte(s) to be measured is organic in nature, the container shall be made of glass. If the analyte(s) is inorganic, then glass or plastic containers may be used. Containers shall be kept out of direct sunlight (to minimize biological or photo-oxidation/photolysis of constituents) until they reach the analytical laboratory. The sample container shall have approximately five to ten percent air space ("ullage") to allow for expansion/vaporization if the sample is heated during transport (one liter of water at 4°C expands by 15 milliliters if heated to 130°F/55°C); however, head space for volatile organic analyses shall be omitted.

The analytical laboratory shall provide sample containers that have been certified clean according to USEPA procedures. Shipping containers for samples, consisting of sturdy ice chests, are to be provided by the laboratory.

Once opened, the sample container must be used at once for storage of a particular sample. Unused, but opened, containers are to be considered contaminated and must be discarded. Because of the potential for introduction of contamination, they cannot be reclosed and saved for later use. Likewise, any unused containers which appear contaminated upon receipt, or which are found to have loose caps or missing liners (if required for the container) shall be discarded.

General sample container, preservative, and holding time requirements are listed in Attachment A.

## **5.2     Preservation Techniques**

The preservation techniques to be used for various analytes are listed in Attachment A. Reagents required for sample preservation will either be added to the sample containers by the laboratory prior to their shipment to the field or added in the field using laboratory supplied preservatives. Some of the more commonly used sample preservation techniques include storage of sample at a temperature of 4°C, acidification of water samples, and storage of samples in dark (i.e. amber) containers to prevent the samples from being exposed to light.

All samples shall be stored at a temperature of 4°C. Additional preservation techniques shall be applied to water samples as follows:

- Water samples to be analyzed for volatile organics shall be acidified.
- Water samples to be analyzed for semivolatile organics shall be stored in dark containers.
- Water samples to be analyzed for pesticides/PCBs shall be stored in dark containers.
- Water samples to be analyzed for inorganic compounds shall be acidified.

These preservation techniques generally apply to samples of low-level contamination. The preservation techniques utilized for samples may vary. However, unless documented otherwise in the project plans, all samples shall be considered low concentration. All samples preserved with chemicals shall be clearly identified by indicating on the sample label that the sample is preserved.

## **5.3     Sample Holding Times**

The elapsed time between sample collection and initiation of laboratory analyses is considered the holding time and must be within a prescribed time frame for each individual analysis to be performed. Sample holding times for routine sample collection are provided in Attachment A.

## **6.0     SAMPLE HANDLING AND TRANSPORTATION**

After collection, the outside of all sample containers will be wiped clean with a damp paper towel; however sample handling should be minimized. Personnel should use extreme care to ensure that samples are not contaminated. If samples are placed in an ice chest, personnel should ensure that melted ice cannot cause sample containers to become submerged, as this may result in sample cross-contamination and loss of sample labels. Sealable plastic bags, (zipper-type bags), should be used when glass sample containers are placed in ice chests to prevent cross-contamination, if breakage should occur.

Samples may be hand delivered to the laboratory or they may be shipped by common carrier. Relevant regulations for the storage and shipping of samples are contained in 40 CFR 261.4(d). Parallel state regulations may also be relevant. Shipment of dangerous goods by air cargo is also regulated by the United Nations/International Civil Aviation Organization (UN/ICAO). The Dangerous Goods Regulations promulgated by the International Air Transport Association (IATA) meet or exceed DOT and UN/ICAO requirements and should be used for shipment of dangerous goods via air cargo. Standard procedures for shipping environmental samples are given in Attachment B.

## 7.0 REFERENCES

American Public Health Association, 1981. Standard Methods for the Examination of Water and Wastewater. 15th Edition. APHA, Washington, D.C.

USEPA, 1984. "Guidelines Establishing Test Procedures for the Analysis of Pollutants under Clean Water Act." Federal Register, Volume 49 (209), October 26, 1984, p. 43234.

USEPA, 1979. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. USEPA EMSL, Cincinnati, Ohio.

USEPA, Region IV, 1991. Environmental Compliance Branch Standard Operating Procedures and Quality Assurance Manual. Athens, Georgia.

Protection of the Environment, Code of Federal Regulation, Title 40, Parts 260 to 299.

Transportation, Code of Federal Regulation, Title 49, Parts 100 to 177.

**ATTACHMENT A**

**REQUIRED CONTAINER, PRESERVATION TECHNIQUES  
AND HOLDING TIMES**

## ATTACHMENT A

### SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR AQUEOUS SAMPLES

Parameter	Bottle Requirements	Preservation Requirements	Holding Time <sup>(1)</sup>	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C 1:1 HCl pH <2	10 days	CLP	2 x 40 ml
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
PCB/Pesticides	glass teflon lined cap	Cool to 4°C Dark	Extraction within 5 days Analyze 40 days	CLP	2 x 1 liter
Cyanide	plastic/glass	NaOH to pH > 12 Cool to 4°C	14 days	CLP EPA 335.2	1 x 1 liter
Metals (TAL)	plastic/glass	HNO <sub>3</sub> to pH <2	180 days except Mercury is 26 days	CLP	1 x 1 liter
Total Organic Carbon	glass, teflon lined cap	Cool to 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days	EPA 415.1	2 x 40 ml
Total Organic Halogen	plastic/glass	Cool to 4°C H <sub>2</sub> SO <sub>4</sub> to pH <2	28 days	EPA 450.1	250 ml
Chloride	plastic/glass	none required	28 days	EPA 325.2/325.3	250 ml
Sulfate	plastic/glass	Cool to 4°C	28 days	EPA 375.4	250 ml
Alkalinity	plastic/glass	Cool to 4°C	14 days	EPA 310.1/310.2	250 ml
Gross alpha/gross beta	plastic/glass	HNO <sub>3</sub> to pH <2	6 months	9310	1 gallon
Chlorinated herbicides	glass, teflon lined cap	Cool to 4°C	14/28 days	EPA 515.1	1000 ml
Hardness	plastic/glass	HNO <sub>3</sub> to pH <2	6 months	EPA 130.2	150 ml

(1) Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991.  
Holding times for Non-CLP methods are based on time of sample collection.

Note: Verify this information with the laboratory that will perform the analyses.

**ATTACHMENT A (Continued)**

**SUMMARY OF CONTAINERS, PRESERVATION, AND HOLDING TIMES FOR SOIL SAMPLES**

Parameter	Bottle Requirements	Preservation Requirements	Holding Time <sup>(1)</sup>	Analytical Method	Bottle Volume
Volatile Organic Compounds (VOA)	glass teflon lined cap	Cool to 4°C	10 days	CLP	1 x 50 gm
Semivolatile Organic Compounds (SVOA)	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 250 gm
PCB/Pesticides	glass teflon lined cap	Cool to 4°C	Extraction within 10 days Analyze 40 days	CLP	1 x 50 gm
Metals (TAL)	plastic/glass	Cool to 4°C	Mercury is 26 days 180 days	CLP	1 x 50 gm
Cyanide	plastic/glass	Cool to 4°C	14 days	CLP EPA 335.2M	1 x 50 gm

<sup>(1)</sup> Holding times for CLP methods are based on Validated Time of Sample Receipt as stated in CLP statement of work of February, 1991.  
Holding times for Non-CLP methods are based on time of sample collection.

**Note:** Verify this information with the laboratory that will perform the analyses.

**ATTACHMENT B**

**SAMPLE SHIPPING PROCEDURES**



## ATTACHMENT B

### SAMPLE SHIPPING PROCEDURES

#### Introduction

Samples collected during field investigations or in response to a hazardous materials incident must be classified by the project leader, prior to shipping by air, as either environmental or hazardous substances. The guidance for complying with U.S. DOT regulations in shipping environmental laboratory samples is given in the "National Guidance Package for Compliance with Department of Transportation Regulations in the Shipment of Environmental Laboratory Samples."

Pertinent regulations for the shipping of environmental samples is given in 40 CFR 261.4(d). Samples collected from process wastewater streams, drums, bulk storage tanks, soil, sediment, or water samples from areas suspected of being highly contaminated may require shipment as dangerous goods/hazardous substance. Regulations for packing, marking, labeling, and shipping of dangerous goods by air transport are promulgated by the United Nations International Civil Aviation Organization (UN/ICAO), which is equivalent to IATA.

Individuals responsible for transportation of environmental samples or dangerous goods/hazardous substances must be tested and certified by their employer. This is required by 49 CFR Part 172 Subpart H Docket HM-126 to assure the required qualifications for individuals offering materials for transportation.

Environmental samples shall be packed prior to shipment by commercial air carrier using the following procedures:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug (inside and outside) with fiber or duct tape. Line the cooler with a large heavy duty plastic bag. This practice keeps the inside of the cooler clean and minimizes cleanup at the laboratory after samples are removed.
2. Allow sufficient headspace (ullage) in all bottles (except VOAs) to compensate for any pressure and temperature changes (approximately 10 percent of the volume of the container).
3. Be sure the lids on all bottles are tight (will not leak). In many regions custody seals are also applied to sample container lids. The reason for this practice is two-fold: to maintain integrity of samples and keep lid on the container should the lid loosen during shipment. Check with the appropriate regional procedures prior to field work. In many cases, the laboratory manager of the analytical lot to be used on a particular project can also provide this information.
4. It is good practice to wrap all glass containers in bubblewrap or other suitable packing material prior to placing in plastic bags.

5. Place all bottles in separate and appropriately sized polyethylene bags and seal the bags with tape (preferably plastic electrical tape, unless the bag is a zipper-type bag). Up to three VOA bottles, separately wrapped in bubblewrap, may be packed in one plastic bag.
6. Optionally, place three to six VOA vials in a quart metal can and then fill the can with vermiculite.
7. Place two to four inches of vermiculite (ground corn cob, or other inert packing material) in the bottom of the cooler and then place the bottles and cans in the cooler with sufficient space to allow for the addition of more vermiculite between the bottles and cans.
8. Put frozen "blue ice" (or ice that has been placed in properly sealed, double-bagged, heavy duty polyethylene bags) on top of and between the samples. Fill all remaining space between the bottles or cans with packing material. Fold and securely fasten the top of the large heavy duty plastic bag with tape (preferably electrical or duct).
9. Place the Chain-of-Custody Record and the Request for Analysis Form (if applicable) into a plastic bag, tape the bag to the inner side of the cooler lid, and then close the cooler and securely tape (preferably with fiber tape) the top of the cooler unit. Wrap the tape three to four times around each side of the cooler unit. Chain-of-custody seals should be affixed to the top and sides of the cooler within the securing tape so that the cooler cannot be opened without breaking the seal.
10. Each cooler (if multiple coolers) should have its own Chain-of-Custody Record reflecting the samples shipped in that cooler.
11. Label according to 40 CFR 261.4(d). The shipping containers should be marked "THIS END UP," and arrow labels which indicate the proper upward position of the container should be affixed to the container. A label containing the name and address of the shipper and laboratory shall be placed on the outside of the container. It is good practice to secure this label with clear plastic tape to prevent removal during shipment by blurring of important information should the label become wet. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill, which is secured to the top of the shipping container. Please note several coolers/shipping containers may be shipped under one airbill. However, each cooler must be labeled as "Cooler 1 of 3, Cooler 2 of 3, etc.", prior to shipping. Additionally it is good practice to label each COC form to correspond to each cooler (i.e., 1 of 3, 2 of 3, etc.).

**APPENDIX R**  
**CHAIN-OF-CUSTODY**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
CHAIN-OF-CUSTODY**

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**Page 1 of 6  
SOP Number: F302  
Effective Date: 04/94**

**TABLE OF CONTENTS**

- 1.0 PURPOSE**
- 2.0 SCOPE**
- 3.0 DEFINITIONS**
- 4.0 RESPONSIBILITIES**
- 5.0 PROCEDURES**
  - 5.1 Sample Identification
  - 5.2 Chain-of-Custody Procedures
- 6.0 QUALITY ASSURANCE RECORDS**
- 7.0 REFERENCES**

**ATTACHMENT A -- EXAMPLE CLIENT (SAMPLE) LABEL**

**ATTACHMENT B -- EXAMPLE CHAIN-OF-CUSTODY RECORD**

## CHAIN-OF-CUSTODY

### 1.0 PURPOSE

The purpose of this SOP is to provide information on chain-of-custody procedures to be used to document sample handling.

### 2.0 SCOPE

This procedure describes the steps necessary for transferring samples through the use of Chain-of-Custody Records. A Chain-of-Custody Record is required, without exception, for the tracking and recording of samples collected for on-site or off-site analysis (chemical or geotechnical) during program activities (except wellhead samples taken for measurement of field parameters). Use of the Chain-of-Custody Record Form creates an accurate written record that can be used to trace the possession and handling of the sample from the moment of its collection through analysis. This procedure identifies the necessary custody records and describes their completion. This procedure does not take precedence over region-specific or site-specific requirements for chain-of-custody.

### 3.0 DEFINITIONS

Chain-of-Custody Record Form - A Chain-of-Custody Record Form is a printed two-part form that accompanies a sample or group of samples as custody of the sample(s) is transferred from one custodian to another custodian. One copy of the form must be retained in the project file. An example of a Chain-of-Custody Record Form is presented in Attachment B.

Custodian - The person responsible for the custody of samples at a particular time, until custody is transferred to another person (and so documented), who then becomes custodian. A sample is under one's custody if:

- It is in one's actual possession.
- It is in one's view, after being in one's physical possession.
- It was in one's physical possession and then he/she locked it up to prevent tampering.
- It is in a designated and identified secure area.

Sample - A sample is physical evidence collected from a facility or the environment, which is representative of conditions at the point and time that it was collected.

### 4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for ensuring that project-specific plans are in accordance with these procedures, where applicable, or that other, approved procedures are developed. The Project Manager is responsible for development of documentation of procedures which deviate from those presented herein. The Project Manager is responsible for ensuring that chain-of-custody procedures are implemented. The Project Manager also is responsible for determining that custody procedures have been met by the analytical laboratory.

Field Team Leader - The Field Team Leader is responsible for determining that chain-of-custody procedures are implemented up to and including release to the shipper or laboratory. It is the responsibility of the Field Team Leader to ensure that these procedures are implemented in the field and to ensure that personnel performing sampling activities have been briefed and trained to execute these procedures.

Sampling Personnel - It is the responsibility of the field sampling personnel to initiate chain-of-custody procedures, and maintain custody of samples until they are relinquished to another custodian, the sample shipper, or to a common carrier.

## **5.0 PROCEDURES**

The term "chain-of-custody" refers to procedures which ensure that evidence presented in a court of law is valid. The chain-of-custody procedures track the evidence from the time and place it is first obtained to the courtroom, as well as providing security for the evidence as it is moved and/or passed from the custody of one individual to another.

Chain-of-custody procedures, record keeping, and documentation are an important part of the management control of samples. Regulatory agencies must be able to provide the chain-of-possession and custody of any samples that are offered for evidence, or that form the basis of analytical test results introduced as evidence. Written procedures must be available and followed whenever evidence samples are collected, transferred, stored, analyzed, or destroyed.

### **5.1 Sample Identification**

The method of identification of a sample depends on the type of measurement or analysis performed. When in-situ measurements are made, the data are recorded directly in bound logbooks or other field data records with identifying information.

Information which shall be recorded in the field logbook, when in-situ measurements or samples for laboratory analysis are collected, includes:

- Field Sampler(s)
- Project and Task Number
- Project Sample Number
- Sample location or sampling station number
- Date and time of sample collection and/or measurement
- Field observations
- Equipment used to collect samples and measurements
- Calibration data for equipment used

Measurements and observations shall be recorded using waterproof ink.

#### **5.1.1 Sample Label**

Samples, other than in-situ measurements, are removed and transported from the sample location to a laboratory or other location for analysis. Before removal, however, a sample is often divided into portions,

depending upon the analyses to be performed. Each portion is preserved in accordance with the Sampling and Analysis Plan. Each sample container is identified by a sample label (see Attachment A). Sample labels are provided, along with sample containers, by the analytical laboratory. The information recorded on the sample label includes:

- Project and Task Number.
- Station Location - The unique sample number identifying this sample.
- Date - A six-digit number indicating the day, month, and year of sample collection (e.g., 12/21/85).
- Time - A four-digit number indicating the 24-hour time of collection (for example: 0954 is 9:54 am., and 1629 is 4:29 p.m.).
- Medium - Water, soil, sediment, sludge, waste, etc.
- Sample Type - Grab or composite.
- Preservation - Type and quantity of preservation added.
- Analysis - VOA, BNAs, PCBs, pesticides, metals, cyanide, other.
- Sampled By - Printed name of the sampler.
- Remarks - Any pertinent additional information.

Using only the work assignment number of the sample label maintains the anonymity of sites. This may be necessary, even to the extent of preventing the laboratory performing the analysis from knowing the identity of the site (e.g., if the laboratory is part of an organization that has performed previous work on the site).

## **5.2 Chain-of-Custody Procedures**

After collection, separation, identification, and preservation, the sample is maintained under chain-of-custody procedures until it is in the custody of the analytical laboratory and has been stored or disposed.

### **5.2.1 Field Custody Procedures**

- Samples are collected as described in the site Sampling and Analysis Plan. Care must be taken to record precisely the sample location and to ensure that the sample number on the label matches the Chain-of-Custody Record exactly.
- The person undertaking the actual sampling in the field is responsible for the care and custody of the samples collected until they are properly transferred or dispatched.

- When photographs are taken of the sampling as part of the documentation procedure, the name of the photographer, date, time, site location, and site description are entered sequentially in the site logbook as photos are taken. Once developed, the photographic prints shall be serially numbered, corresponding to the logbook descriptions; photographs will be stored in the project files. It is good practice to identify sample locations in photographs by including an easily read sign with the appropriate sample/location number.
- Sample labels shall be completed for each sample, using waterproof ink unless prohibited by weather conditions, e.g., a logbook notation would explain that a pencil was used to fill out the sample label if the pen would not function in freezing weather.

### 5.2.2 Transfer of Custody and Shipment

Samples are accompanied by a Chain-of-Custody Record Form. When transferring the possession of samples, the individual(s) relinquishing and receiving will sign, date, and note the time on the Record. This Record documents sample custody transfer from the sampler, often through another person, to the analyst in the laboratory. The Chain-of-Custody Record is filled out as given below.

- Enter header information (Project and Task number, samplers, and project name).
- Enter sample specific information (sample number, media, sample analysis required and analytical method, grab or composite, number and type of sample containers, and date/time sample was collected).
- Sign, date, and enter the time under "Relinquished by" entry.
- Have the person receiving the sample sign the "Received by" entry. If shipping samples by a common carrier, print the carrier to be used in this space (i.e., Federal Express).
- If a carrier is used, enter the airbill number under "Remarks," in the bottom right corner.
- Place the original (top, signed copy) of the Chain-of-Custody Record Form in a plastic zipper-type bag or other appropriate sample shipping package. Retain the copy with field records.
- Sign and date the custody seal, a 1- by 3-inch white paper label with black lettering and an adhesive backing. Attachment C is an example of a custody seal. The custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field. Custody seals shall be provided by the analytical laboratory.
- Place the seal across the shipping container opening so that it would be broken if the container was to be opened.
- Complete other carrier-required shipping papers.



The custody record is completed using waterproof ink. Any corrections are made by drawing a line through and initialing and dating the change, then entering the correct information. Erasures are not permitted.

Common carriers will usually not accept responsibility for handling Chain-of-Custody Record Forms; this necessitates packing the record in the shipping container (enclosed with other documentation in a plastic zipper-type bag). As long as custody forms are sealed inside the shipping container and the custody seals are intact, commercial carriers are not required to sign the custody form.

The laboratory representative who accepts the incoming sample shipment signs and dates the Chain-of-Custody Record, completing the sample transfer process. It is then the laboratory's responsibility to maintain internal logbooks and custody records throughout sample preparation and analysis.

## **6.0 QUALITY ASSURANCE RECORDS**

Once samples have been packaged and shipped, the COC copy and airbill receipt becomes part of the Quality Assurance Record.

## **7.0 REFERENCES**

1. USEPA. User's Guide to the Contract Laboratory Program. Office of Emergency and Remedial Response, Washington, D.C. (EPA/540/P-91/002), January 1991.

**ATTACHMENT A**  
**EXAMPLE CLIENT (SAMPLE) LABEL**

EXAMPLE SAMPLE LABEL

<b>Baker</b>	Baker Environmental Inc. Airport Office Park, Bldg. 3 420 Rouser Road Coraopolis, PA 15108
Project: <u>19026-SRN</u>	CTO No.: <u>0026</u>
Sample Description: <u>Groundwater</u>	
Date: <u>09/17/92</u>	Sampler: <u>ABC</u>
Time: <u>0944</u>	
Analysis: <u>TAL Metals (CAP)</u> Preservation: <u>HNO<sub>3</sub></u>	
Project Sample No.: <u>CAX-GW-04</u>	

Note: Typically, sample labels are provided by the analytical laboratory and may be used instead of the above. However, samplers should make sure all pertinent information can be affixed to the label used.

**ATTACHMENT B**

**EXAMPLE CHAIN-OF-CUSTODY RECORD**



**Baker Environmental, Inc.**  
Airport Office Park, Bldg. 3  
420 Rouser Road  
Coraopolis, PA 15108  
412-269-6000  
412-269-6097 (fax)

# CHAIN-OF-CUSTODY RECORD

Pg. \_\_\_\_ of \_\_\_\_

Lab and BOA #: \_\_\_\_\_  
 Delivery Order # \_\_\_\_\_  
 Project Number: \_\_\_\_\_  
 Project Name: \_\_\_\_\_  
 Field Team: \_\_\_\_\_  
 SEND RESULTS TO: \_\_\_\_\_

[illegible]

<p>Relinquished By: _____ Date: _____ Time: _____</p> <p>Received By: _____ Date: _____ Time: _____</p> <p>Shipped by (check one): Hand <input type="checkbox"/> Overnight <input type="checkbox"/> Other <input type="checkbox"/> _____</p>	<p>Sample Stored at 4 Degrees C: Yes <input type="checkbox"/> No <input type="checkbox"/></p> <p>Chain-of-custody seal on cooler: Yes <input type="checkbox"/> Number: _____ No <input type="checkbox"/></p> <p>Analysis turnaround: Priority <input type="checkbox"/> _____ hrs. Regular <input type="checkbox"/></p> <p>See Work Order <input type="checkbox"/></p> <p>See Analysis Request Form <input type="checkbox"/></p>															
<p>Relinquished By: _____ Date: _____ Time: _____</p> <p>Received By: _____ Date: _____ Time: _____</p> <p>Shipped by (check one): Hand <input type="checkbox"/> Overnight <input type="checkbox"/> Other <input type="checkbox"/> _____</p>	<p>Sample Disposal Return to Baker <input type="checkbox"/> Lab Disposal <input type="checkbox"/></p> <p>Archive until: _____ (date)</p>															
<p>Relinquished By: _____ Date: _____ Time: _____</p> <p>Received By: _____ Date: _____ Time: _____</p> <p>Shipped by (check one): Hand <input type="checkbox"/> Overnight <input type="checkbox"/> Other <input type="checkbox"/> _____</p>	<p>NOTES:</p> <table style="width: 100%;"> <tr> <td style="width: 33%;">(1) A - Air</td> <td style="width: 33%;">SB - SubSurface Soil</td> <td style="width: 33%;">(2) GB - Grab</td> </tr> <tr> <td>GW - Groundwater</td> <td>SW - Surface Water</td> <td>COM - Composite</td> </tr> <tr> <td>L - Leachate</td> <td>W - Waste</td> <td>(3) P - Plastic</td> </tr> <tr> <td>S - Spring</td> <td>WP - Wipe</td> <td>G - Glass</td> </tr> <tr> <td>SS - Surface Soil</td> <td>WW - Wastewater</td> <td></td> </tr> </table>	(1) A - Air	SB - SubSurface Soil	(2) GB - Grab	GW - Groundwater	SW - Surface Water	COM - Composite	L - Leachate	W - Waste	(3) P - Plastic	S - Spring	WP - Wipe	G - Glass	SS - Surface Soil	WW - Wastewater	
(1) A - Air	SB - SubSurface Soil	(2) GB - Grab														
GW - Groundwater	SW - Surface Water	COM - Composite														
L - Leachate	W - Waste	(3) P - Plastic														
S - Spring	WP - Wipe	G - Glass														
SS - Surface Soil	WW - Wastewater															

**White - Return with analytical results;      Yellow - Laboratory Copy;      Pink - Field Copy**

**Courier Name:** \_\_\_\_\_  
**Courier Pickup Number:** \_\_\_\_\_  
**File Name:** \_\_\_\_\_

**ATTACHMENT C**  
**EXAMPLE CUSTODY SEAL**

**EXAMPLE CUSTODY SEAL**

<b>Baker</b>	____/____/____ Date
	_____ Signature
	<b>CUSTODY SEAL</b>

<b>Baker</b>	____/____/____ Date
	_____ Signature
	<b>CUSTODY SEAL</b>

**APPENDIX S**  
**FIELD LOGBOOK**

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**FIELD EQUIPMENT OPERATION AND  
MAINTENANCE PROCEDURES -  
FIELD LOGBOOK**

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**Page 1 of 4  
SOP Number: F303  
Effective Date: 04/94**

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**TABLE OF CONTENTS**

<b>1.0</b>	<b>PURPOSE</b>
<b>2.0</b>	<b>SCOPE</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>RESPONSIBILITIES</b>
<b>5.0</b>	<b>PROCEDURES</b>
5.1	Cover
5.2	Daily Entries
5.3	Photographs
<b>6.0</b>	<b>QUALITY ASSURANCE RECORDS</b>
<b>7.0</b>	<b>REFERENCES</b>

## **FIELD LOGBOOK FIELD LOGBOOK**

### **1.0 PURPOSE**

This SOP describes the process for maintaining a field logbook.

### **2.0 SCOPE**

The field logbook is a document which records all major on-site activities conducted during a field investigation. At a minimum, the following activities/events shall be recorded in the field logbook by each member of the field crew.

- Arrival/departure of site workers and visitors
- Arrival/departure of equipment
- Sample pickup (sample numbers, carrier, time)
- Sampling activities
- Start or completion of boreholes, monitoring wells, or sampling activities
- Health and safety issues

The field logbook is initiated upon arrival at the site for the start of the first on-site activity. Entries are made every day that on-site activities take place. At least one field logbook shall be maintained per site.

The field logbook becomes part of the permanent site file. Because information contained in the field logbook may be admitted as evidence in legal proceedings, it is critical that this document is properly maintained.

### **3.0 DEFINITIONS**

Field logbook - The field logbook is a bound notebook with consecutively numbered pages. Upon entry of data, the logbook requires the signature of the responsible data/information recorder.

### **4.0 RESPONSIBILITIES**

The Field Team Leader is responsible for maintaining a master field logbook for the duration of on-site activities. Each member of the sampling crew is responsible for maintaining a complete and accurate record of site activities for the duration of the crew members participation in the project.

### **5.0 PROCEDURES**

The following sections present some of the information that must be recorded in the field logbook. In general, a record of all events and activities, as well as other potentially important information shall be recorded by each member of the field team.

## 5.1 Cover

The inside cover or title page of each field logbook shall contain the following information:

- Project and Task Number
- Project name and location
- Name of Field Team Leader
- Baker's address and telephone number
- Start date
- If several logbooks are required, a sequential field logbook number

It is good practice to list important phone numbers and points of contact here.

## 5.2 Daily Entries

Daily entries into the logbook may contain a variety of information. At the beginning of each day the following information must be recorded by each team member.

- Date
- Start time
- Weather
- All field personnel present
- All visitors present
- Other pertinent information (i.e., planned activities, schedule changes, expected visitors, and equipment changes)

During the day, an ongoing record of all site activities should be written in the logbook. The master logbook kept by the field team leader need not duplicate that recorded in other field logbooks, but should summarize the information in other books and, where appropriate, reference the page numbers of other logbooks where detailed information pertaining to a subject may be found.

Some specific information which must be recorded in the logbook includes the following:

- Equipment used, equipment numbers, calibration, field servicing
- Field measurements
- Sample numbers, media, bottle size, preservatives, collection methods, and time
- Test boring and monitoring well construction information, including boring/well number and location
- Sketches for each sample location including appropriate measurements if required
- Photograph log
- Drum log
- Other pertinent information

All entries should be made in indelible ink; all pages numbered consecutively; and all pages must be signed or initialed and dated by the responsible field personnel completing the log. No erasures are permitted. If an incorrect entry is made, the entry shall be crossed out with a single line, initialed, and dated.

### **5.3     Photographs**

If photographs are permitted at the site, the record shall be maintained in the field logbook. When movies, slides or photographs are taken of any site location, they are numbered or cross-referenced to correspond to logbook entries. The name of the photographer, date, time, site location, site description, direction of view and weather conditions are entered in the logbook as the photographs are taken. Special lenses, film, or other image-enhancement techniques also must be noted in the field logbook. Once processed, photographs shall be serially numbered and labeled corresponding to the field logbook entries.

### **6.0     QUALITY ASSURANCE RECORDS**

Once on-site activities have been completed, the field logbook shall be considered a quality assurance record.

### **7.0     REFERENCES**

None.

**FINAL**

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
QUALITY ASSURANCE PROJECT PLAN  
SITE 84/BUILDING 45 AREA  
MCB CAMP LEJEUNE, NORTH CAROLINA  
CONTRACT TASK ORDER 0139 (CLEAN II)**

**JUNE 2001**

*Prepared for:*

**DEPARTMENT OF THE NAVY  
ATLANTIC DIVISION  
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ENGINEERING COMMAND  
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## TABLE OF CONTENTS

	<u>Page</u>
<b>1.0 INTRODUCTION .....</b>	<b>1-1</b>
<b>2.0 SCOPE OF QUALITY ASSURANCE PROJECT PLAN.....</b>	<b>2-1</b>
<b>3.0 PROJECT DESCRIPTION.....</b>	<b>3-1</b>
<b>4.0 PROJECT ORGANIZATION .....</b>	<b>4-1</b>
<b>5.0 QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT .....</b>	<b>5-1</b>
5.1 Project Quality Assurance Objectives.....	5-1
5.2 Data Quality Objectives.....	5-2
<b>6.0 SAMPLE AND DOCUMENT CUSTODY PROCEDURES .....</b>	<b>6-1</b>
6.1 Sampling Handling.....	6-1
6.2 Chain-of-Custody Procedures.....	6-1
6.3 Document Custody Procedures.....	6-3
<b>7.0 CALIBRATION PROCEDURES AND FREQUENCY .....</b>	<b>7-1</b>
7.1 Field Instruments .....	7-1
7.2 Laboratory Instruments.....	7-1
7.2.1 Method Calibration .....	7-2
7.2.2 GC/MS System Calibration Procedure .....	7-2
7.2.3 GC System Calibration Procedure for Pesticides/PCBs.....	7-3
7.2.4 System Calibration Procedure for GC Purgable Aromatics .....	7-3
7.2.5 System Calibration Procedure for Metals Analysis.....	7-4
7.2.6 System Calibration Procedure for Inorganic Analyses.....	7-5
7.2.7 Periodic Calibration.....	7-5
<b>8.0 ANALYTICAL PROCEDURES.....</b>	<b>8-1</b>
8.1 Field Analysis.....	8-1
8.2 Laboratory Analysis.....	8-1
<b>9.0 DATA REDUCTION, VALIDATION AND REPORTING.....</b>	<b>9-1</b>
9.1 Field Data Procedures.....	9-1
9.2 Laboratory Data Procedures.....	9-1
9.2.1 Laboratory Data Validation .....	9-1
9.2.2 Analytical Reports .....	9-2
9.3 Independent (Third Party) Data Validation.....	9-2
<b>10.0 INTERNAL QUALITY CONTROL CHECKS.....</b>	<b>10-1</b>
10.1 Field Quality Control Checks .....	10-1
10.2 Laboratory Quality Control Checks .....	10-2
10.3 Laboratory Control Limits .....	10-3
<b>11.0 PREVENTIVE MAINTENANCE .....</b>	<b>11-1</b>
11.1 Field Maintenance .....	11-1
11.2 Laboratory Maintenance .....	11-1

**TABLE OF CONTENTS**  
**(Continued)**

	<u>Page</u>
<b>12.0 DATA MEASUREMENT ASSESSMENT PROCEDURES .....</b>	<b>12-1</b>
12.1 Overall Project Assessment .....	12-1
12.2 Field Quality Assessment .....	12-1
12.3 Laboratory Data Quality Assessment.....	12-1
<b>13.0 CORRECTIVE ACTION .....</b>	<b>13-1</b>
13.1 Limits of Operation.....	13-1
13.2 Corrective Action.....	13-1
<b>14.0 QUALITY ASSURANCE REPORTING PROCEDURES.....</b>	<b>14-1</b>

**LIST OF TABLES**

5-1	Definitions of Data Quality Indicators Remedial Investigation/Feasibility Study
6-1	Summary of Aqueous Sample Container, Preservative and Holding Time Remedial Investigation/Feasibility Study
6-2	Summary of Soil/Sediment Sample Container, Preservation and Holding Time Remedial Investigation/Feasibility Study
8-1	Method Performance Limits Remedial Investigation/Feasibility Study
10-1	QA/QC Sample Frequency Remedial Investigation/Feasibility Study
10-2	QC Analysis Frequency Remedial Investigation/Feasibility Study

**LIST OF FIGURES**

4-1	Project Organization
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## LIST OF ACRONYMS AND ABBREVIATIONS

AA	atomic absorption
ASTM	American Society of Testing and Materials
Baker	Baker Environmental, Inc.
BFB	p-bromofluorobenzene
CCC	Calibration Check Compound
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
COC	Chain-of-Custody
CRDL	Contract Required Detection Limit
CTO	Contract Task Order
DFTPP	decafluorotri-phenylphosphine
DoN	Department of the Navy
DQO	Data Quality Objective
FSAP	Field Sampling and Analysis Plan
GC/MS	Gas Chromatograph/Mass Spectrometer
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LEL	Lower Explosive Limit
MCB	Marine Corps Base
MDL	Method Detection Limit
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NBS	National Bureau of Standards
NFESC	Naval Facilities Engineering Service Center
NTR	Navy Technical Representative
PEM	Performance Evaluation Mixtures
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RI/FS	Remedial Investigation/Feasibility Study
RRF	Relative Response Factor
SOP	Standard Operating Procedures
USEPA	United States Environmental Protection Agency
VOC	volatile organic compounds



## **1.0 INTRODUCTION**

This Quality Assurance Project Plan (QAPP) has been developed for the field investigation at Site 84 Building 45 Area, Marine Corps Base (MCB), Camp Lejeune, North Carolina.

The preparation of this QAPP, and other related project plans, is being performed under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV) under the Comprehensive Long-Term Environmental Action - Navy (CLEAN II) Contract N62470-95-D-6007 Contract Task Order (CTO) 0139.

This QAPP addresses the quality assurance and quality control steps and procedures that will be administered for the sample collection and analysis for this Remedial Investigation/Feasibility Study (RI/FS). Detailed information regarding sample handling and analytical methods are provided in Sections 6.0 and 9.0, respectively. Sample collection procedures are provided in the Field Sampling and Analysis Plan (FSAP).

## 2.0 SCOPE OF QUALITY ASSURANCE PROJECT PLAN

This Quality Assurance Project Plan (QAPP) addresses sample collection and analysis to be conducted for the field investigation at Site 84 of MCB Camp Lejeune, North Carolina. The QAPP has been developed for the Department of Navy (DoN) in accordance with U.S. Environmental Protection Agency (USEPA) guidelines. Contractors will follow QA/QC practices and procedures, including chain-of-custody procedures, while conducting all sample collection and analysis activities.

In order to provide adequate QA/QC, this investigation will require:

1. The use of a NFESC -certified analytical laboratory;
2. The use of accepted analytical methods for the samples discussed in the FSAP. Analysis of samples for hazardous constituents parameters will be performed using the following documents:
  - "Statement of Work for Organic Analysis," USEPA, OLM03.1, August 1994
  - "Statement of Work for Inorganic Analysis," USEPA, ILM02.0, March 1994
  - "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983
  - "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136
  - "Test Methods for Evaluating Solid Waste, SW 846," USEPA, June 1997
  - "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886

The structure of this QAPP and the Quality Assurance (QA) elements addressed are:

- Title Page
- Table of Contents
- Introduction
- Scope of QAPP
- Project Description
- Project Organization
- QA Objectives for Data Measurement
- Sample and Document Custody Procedures
- Calibration Procedures and Frequency
- Analytical Procedures
- Data Reduction, Validation, and Reporting
- Internal QC Checks
- Performance and System Audits
- Preventive Maintenance
- Data Measurement Assessment Procedures
- Corrective Action
- QA Reporting Procedures

### **3.0 PROJECT DESCRIPTION**

An introduction to the field investigation at Site 84 describing the project objectives and scope are given in Sections 3.0 and 4.0 of the Remedial Investigation/Feasibility Study (RI/FS) Work Plan. These sections discuss the objectives of the RI/FS, and the various field sampling and analytical programs. A detailed description of the field investigations, including sample location and designation, and sampling procedures and frequency, is presented in Sections 4.0, 5.0, and 6.0 of the RI/FS Field Sampling and Analysis Plan (FSAP).

#### **4.0 PROJECT ORGANIZATION**

Technical performance of the investigation of Site 84 at MCB Camp Lejeune and key personnel responsible for quality assurance throughout its duration are described in Section 5.0 of the RI/FS Work Plan. The contractor will utilize subcontractors to perform laboratory analysis, data validation, drilling and monitoring well installation, and surveying. Specific subcontractors have not yet been identified. Figure 4-1 shows the project organization, lines of authority, and support personnel/organizations.

## 5.0 QUALITY ASSURANCE OBJECTIVES FOR DATA MEASUREMENT

The purpose of a QA Program is to establish policies for the implementation of regulatory requirements and to provide an internal means for control and review so that the work performed is of the highest professional standards.

### 5.1 Project Quality Assurance Objectives

The following is a list of QA objectives which will be implemented at Camp Lejeune Site 84.

- Obtain scientific data of a quality sufficient to meet scientific and legal scrutiny.
- Gather/develop data in accordance with procedures appropriate for its intended use.
- Ensure that data is of acceptable precision, accuracy, completeness, representativeness, and comparability as required by the project.

The fundamental mechanisms that will be employed to achieve these quality goals can be categorized as prevention, assessment and correction where:

- Prevention of errors through planning, documented instructions and procedures, and careful selection and training of skilled, qualified personnel.
- Assessment of all quality assurance sampling reports furnished by the contract laboratory.
- Assessment of data through data validation, and of procedures through laboratory and field audits.
- Correction for prevention of reoccurrence of conditions adverse to quality.

This QAPP, prepared in direct response to these goals, describes the QA Program to be implemented and the quality control (QC) procedures to be followed by field and laboratory personnel during the course of the project.

This QAPP presents the project organization and specifies or references technical procedures, documentation requirements, sample custody requirements, audit, and corrective action provisions to be applied to provide confidence that all activities meet the intent of the QA program. This QAPP has been prepared in accordance with USEPA guidance as presented in "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80.

The procedures contained or referred to herein have been taken from:

- "Statement of Work for Organic Analysis," USEPA , OLM01.8, August 1991
- "Statement of Work for Inorganic Analysis," USEPA , ILM03.0, March 1990
- "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983

- "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136
- "Test Methods for Evaluating Solid Waste," USEPA SW846, November 1986, 3rd Edition
- "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886
- "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," USEPA, (QAMS 005/80).

## **5.2 Data Quality Objectives**

Data quality objectives (DQOs) are qualitative or quantitative statements developed by the data users to specify the quality of data needed from a particular data collection activity to support a specific decision. The DQOs are expressed in terms of precision, accuracy, representativeness, completeness, and comparability. Definitions for these terms, as well as for the more general term uncertainty, are given in Table 5-1

The Project Manager, in conjunction with the Navy Environmental Technical Representative (NTR), is responsible for defining the DQOs. The intended use of the data, analytical measurements, and the availability of resources are integral in development of DQOs. DQOs define the level of uncertainty in the data that is acceptable for each specific activity during the investigation. This uncertainty includes both field sampling error and analytical instrument error. Ideally, zero uncertainty is the goal; however, the variables associated with sampling and analysis contribute to a degree of uncertainty in any data generated. It is an overall program objective to keep the total uncertainty within an acceptable range, so as not to hinder the intended use of the data. To achieve this objective, specific data quality requirements such as detection limits, criteria for accuracy and precision, sample representativeness, data comparability, and data completeness have been specified.

The data collected will be used:

- To evaluate the presence or absence of contamination resulting from previous disposal activities.
- To assess potential contaminant migration and exposure pathways.
- To monitor health and safety conditions during field activities.
- To identify releases or suspected releases of hazardous waste and/or constituents.
- To screen from further investigation those areas which do not pose a threat to human health or environment.

All samples for characterizing the site or qualitatively assessing human health and environmental risks will be analyzed and reported by the laboratory as Level III data (NFESC Level D). Level II data related to the ENSYS field screening analyses. Field parameters including temperature (aqueous only) and specific conductance will be Level I (NFESC Level A) data quality.

## **6.0 SAMPLE AND DOCUMENT CUSTODY PROCEDURES**

Descriptions of the procedures to be used for sampling the groundwater, surface water, sediment and soil at the site are provided in the FSAP. The number of samples, sampling locations, and sampling rationale by media also are presented in Section 4.0 of the FSAP.

Sample custody procedures outlined in this section have been developed from "User's Guide to the Contract Laboratory Program," December 1988, OSWER Directive No. 9240.0-01. These procedures are in accordance with "EPA NEIC Policies and Procedure Manual," May 1978, revised November 1984, EPA 330-78-001-R and "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," December 1980, QAMS-005/80.

The purpose of this section is to outline the sample handling and sample documentation procedures to be used during implementation of the FSAP. The objective of the sample handling procedures is to deliver representative samples to the laboratories for analysis. The objectives of the sample documentation procedures are to: (1) ensure complete analysis of the requested parameters within the required turnaround times; and (2) document the sample from the point of collection to the final data report.

### **6.1 Sample Handling**

New polyethylene or glass bottles containing the proper preservatives will be provided by the laboratory for sample collection. In addition to the chemical preservatives, samples will be stored on ice at 4°C in a waterproof metal or sturdy plastic cooler, if required (see Tables 6-1 and 6-2).

### **6.2 Chain-of-Custody Procedures**

A sample is considered to be in an individual's possession if:

- It is in the sampler's possession or it is in the sampler's view after being in his or her possession.
- It was in the sampler's possession and then locked or sealed to prevent tampering.
- It is in a secure area.

Five kinds of documentation will be used in tracking and shipping the analytical samples:

- Field log book
- Sample labels
- Chain-of-Custody (COC) records
- Custody seals
- Commercial carrier airbills

At a minimum, the label for each sample bottle will contain the following information:

- Site name
- Sample number
- Date and time of collection
- Sample type (grab or composite)
- Matrix

- Sampler's initials

The sample information, as well as the analysis to be performed on the sample, will be entered in the field log book for each sampling point. Additionally, the following items will be entered:

- Dates and times of entry
- Names of field personnel on site
- Names of visitors on site
- Field conditions
- Description of activities
- Sampling remarks and observations
- QA/QC samples collected
- List of photographs taken
- Sketch of site conditions

Custody of the samples will be maintained by field personnel from the time of sampling until the time they are forwarded to the analytical laboratory.

The sample custody is documented using Chain-of-Custody (COC) records. Field personnel will complete a COC record, in waterproof ink, to accompany each cooler forwarded from the site to the laboratory. Chemical reagents used to preserve the samples will be recorded on the COC record. Any errors on the COC records will not be erased; instead, a line will be drawn through the error and initialed by the person completing the form. The original copy will be placed in a sealable plastic bag and put inside the appropriate cooler, secured to the cooler's lid.

If the sample cooler is to be shipped by commercial air carrier, the cooler must be secured with custody seals so that the seals would be broken if the cooler was opened. The commercial carrier is not required to sign the COC record as long as the custody seals remain intact and the COC record stays in the cooler. The only other documentation required is the completed airbill.

If the sample shipment is hand delivered to the laboratory by field personnel or retrieved by laboratory personnel at the site, then the custody seals are not necessary. The laboratory sample custodian, or his/her designee accepting the sample shipment, whether it is from the air carrier or the field personnel, signs and dates the COC record upon sample receipt. The original COC record will be returned along with the final data report. The laboratory will be responsible for maintaining internal log books and records that provide a custody record during sample preparation and analysis.

### **Laboratory Chain-of-Custody Procedures**

Upon sample receipt the following steps will be performed.

- Samples will be received and unpacked in the laboratory where the staff checks for bottle integrity (loose caps, broken bottles, etc.).
- Samples will be verified with incoming paperwork (packing slip, etc.) by type of bottle and stabilizer. The paperwork must be either signed or initialed.
- Information concerning the sample (from the sampling record, Chain-of-Custody, and observation) will be recorded along with parameters to be analyzed, date of sampling, and date the sample is received in the laboratory.



- Samples will be placed in an appropriate secured storage area until analysis.
- When analysis is complete, samples will be stored for a 30-day period unless otherwise specified.

If collected samples arrive without Chain-of-Custody or incorrect Chain-of-Custody records, the following steps will be taken:

- The laboratory will prepare a nonconformance form stating the problem.
- The site supervisor and Project Manager will be notified.
- If the missing information cannot be provided by the field staff, the samples affected will not be analyzed.

Primary considerations for sample storage are:

- Secured storage.
- Maintain prescribed temperature, if required, which is typically four degrees Celsius.
- Extract and/or analyze samples within the prescribed holding time for the parameters of interest.

### **6.3 Document Custody Procedures**

Project records are necessary to support the validity of the work and to furnish documentary evidence of quality. The evidentiary value of data is dependent upon the proper maintenance and retrieval of quality assurance records. Therefore, procedures will be established to assure that all documents attesting to the validity of work can be accounted for when the work is completed.

Records must be legible, filled out completely, and adequately identified as to the item or activity involved. Records will be considered valid only if initialed, signed, or otherwise authenticated and dated by authorized personnel. These records may either be originals or reproduced copies. Records submitted to the files, with the exception of correspondence, will be bound, placed in folders or binders, or otherwise secured for filing.

Following receipt of information from external sources, completion of analyses, and issuance of reports or other transmittals, associated records will be submitted to the proper file. In addition, transmitted records must be adequately protected from damage and loss during transfer (e.g. hand carrying or making copies prior to shipment).

The following documents will be transferred to the proper files during the course of the project: calculations and checkprints; reports and other data transmittals; copies of proposals, purchase orders for project services, and contracts; correspondence including incoming and outgoing letters, memoranda, and telephone records; and reference material.

All individuals on the project staff will be responsible for reporting obsolete or superseded project-related information to the Project Manager. In turn, the Project Manager will notify the project and laboratory staffs of the resulting status change in project documents, such as drawings and project procedures.

In general, outdated drawings and other documents will be marked "void." However, the Project Manager may request the copies be destroyed. One copy of void documents is maintained in the project files with the reasons, and date of voiding clearly indicated.

Documents will be marked "preliminary" to denote calculations and other material which have not been formally checked, or based on information which has not been checked, or do not contribute to final project information.

## **7.0 CALIBRATION PROCEDURES AND FREQUENCY**

The following section describes calibration procedures and frequency.

### **7.1 Field Instruments**

Three field instruments will be used for health and safety monitoring: the O<sub>2</sub>/LEL meter, the HNu System portable photoionizer and the MiniRam (dust monitor). These instruments will be calibrated on site daily according to the manufacturer's instructions, in addition to the factory calibration it will receive prior to the start of site sampling. The calibration standards will be recorded in the field log book.

A pH meter, conductivity thermometer and turbidity meter will be used to analyze groundwater and surface water samples. Procedures from "Test Methods for Evaluating Solid Waste," USEPA, SW846, November 1986, 3rd Edition will be used to calibrate these meters. Specific procedures for the calibration of water quality instruments are presented in the FSAP.

### **7.2 Laboratory Instruments**

The laboratory's procedures for calibration and related quality control measures will be conducted according to the protocols presented in the following documents:

- "Statement of Work for Organic Analysis," USEPA, OLM03.1, August 1994
- "Statement of Work for Inorganic Analysis," USEPA, ILM02.0, March 1994
- "Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," USEPA, July 1982
- "Methods for Chemical Analysis of Water and Waste," USEPA, 1979, Revised March 1983
- "Environmental Protection Agency Regulations on Test Procedures for Analysis of Pollutants," USEPA, 40 CFR 136
- "Test Methods for Evaluating Solid Waste," USEPA SW846, June 1997
- "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52 FR 26886

Formal calibration procedures will be established to ensure that instrumentation and equipment used for sample analysis are accurately calibrated and properly functioning. These procedures will apply to all instruments and equipment quantities. All calibrations will be performed by laboratory personnel or external agencies using standard reference materials.

All calibrations will be recorded on in-house calibration forms or instrument vendor forms or in dedicated bound notebooks. The following data will be recorded for all calibrations: the date, target readings, actual readings, instrument identification number, and the analyst's initials. Other data may be recorded depending upon the calibration performed.

Only properly calibrated and operating equipment and instrumentation will be used. Equipment and instrumentation not meeting the specified calibration criteria will be segregated from active equipment whenever possible. Such equipment will be repaired and recalibrated before reuse. All equipment will be uniquely identified, either by serial number or internal calibration number, to allow traceability between equipment and calibration records. Recognized procedures (ASTM, USEPA, or manufacturer's procedures) will be used for calibration whenever available.

#### **7.2.1 Method Calibration**

Method calibration will be performed as part of the laboratory analytical procedure (i.e., calibration curves, tuning). Calibration curves will be prepared using five standards in graduated amounts across the appropriate range of analysis. New calibration curves will be prepared whenever new reagents or standards are prepared or yearly, whichever is more frequent.

#### **7.2.2 GC/MS System Calibration Procedure**

This section outlines the requirements for the calibration of GC/MS systems for the determination of organic compounds. The following operations will be performed in support of these requirements:

- Documentation of GC/MS mass calibration and abundance pattern
- Documentation of GC/MS response factor stability
- Internal standard response and retention time monitoring

#### Tuning and Mass Calibration

It will be necessary to establish that a given GC/MS system meets the standard mass spectral abundance criteria prior to initiating data collection. This will be accomplished through the analysis of p-bromofluorobenzene (BFB) for volatile compounds or decafluorotri-phenylphosphine (DFTPP) for semivolatile compounds. The BFB or DFTPP criteria must be met before any blanks, standards, or samples are analyzed.

A GC/MS system used for organic compound analysis will be tuned to meet the criteria specified for BFB analysis (volatile compounds) or DFTPP (semivolatile compounds) for an injection of 50 nanograms (ng) of BFB or DFTPP. The analysis must be performed separately from standard or blank analysis. These criteria will be demonstrated every 12 hours of operation. Professional judgment must be used to determine whether background subtraction is required to eliminate column bleed or instrument background (i.e., noise). Calibration documentation will be in the form of a bar graph spectrum and a mass listing.

#### GC/MS System Calibration

After tuning criteria have been met and prior to sample analysis, the GC/MS system is initially calibrated at five concentrations utilizing the compounds to be analyzed to determine the linearity of response. Internal and surrogate standards will be used with each calibration standard. Standards will be analyzed under the same conditions as the samples.

- Relative Response Factor (RRF) Calculation – The USEPA specifies the internal standard to be used on a compound-by-compound basis for quantification. The relative response factor (RRF) will be calculated for each compound at each concentration level.

- Continuing Calibration - A calibration check standard containing all semivolatile or volatile compounds and surrogates will be run every 12 hours of analysis. A system performance check will also be performed. The criteria will be the same as for the initial calibration system performance check. A calibration check will also be performed. The percent difference will be determined for each Calibration Check Compound (CCC).

The percent difference for each CCC must be less than or equal to 25.0 percent. The system performance check and calibration check criteria must be met before sample analysis can be performed. The continuing calibration will be recorded on the continuing calibration forms.

### **7.2.3 GC System Calibration Procedure for Pesticides/PCBs**

This section outlines the requirements for the calibration of GC systems for the determination of pesticides/PCBs. The following operations are performed in support of these requirements:

Three types of analyses will be used to verify the calibration and evaluate instrument performance. The analyses of instrument blanks, Performance Evaluation Mixtures (PEMs), and the mid-point concentration of the individual standard mixtures A and B constitute the continuing calibration.

For pesticide/PCB analysis, it is necessary to establish resolution criteria by performing a Resolution Check Mixture where the depth of the valley of two adjacent peaks must be greater than or equal to 60.0 percent of the height of the shorter peak.

The breakdown of DDT and Endrin in both of the PEMs must be less than 20.0 percent and the combined breakdown of DDT and Endrin must be less than 30.0 percent. All peaks in both the Performance Evaluation Mixtures must be 100 percent resolved on both columns.

The absolute retention times of each of the single component pesticides and surrogates in both of the PEMs must be within the retention time windows determined from the three point initial calibration.

The relative percent difference of the calculated amount and the true amount for each of the single component pesticides and surrogates in both of the PEMs must be less than or equivalent to 25.0 percent.

At least one chromatogram between any two adjacent peaks in the midpoint concentrations of Individual Standard Mixtures A and B in the initial calibration must be greater than or equal to 90.0 percent.

### **7.2.4 System Calibration Procedure for GC Purgable Aromatics**

The system must be calibrated daily by external calibration. A minimum of three concentration levels, of each parameter, is used to prepare a calibration curve. The working calibration curve must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than plus or minus ten percent, the test must be repeated using a fresh calibration standard.

The laboratory must spike and analyze a minimum of ten percent of all samples to monitor continuing laboratory performance.

Prior to analysis, the system must be demonstrated to be free from contamination, under the conditions of the analysis, by running a laboratory reagent blank.

The retention time window used to make the identification should be based upon measurements of actual retention time variations of standards over the course of the day.

If the response peak exceeds the working range of the system, prepare a dilution of the sample with reagent water and reanalyze.

### **7.2.5 System Calibration Procedure for Metals Analysis**

This section outlines the requirements for the calibration of atomic absorption (AA) and Inductively Coupled Plasma (ICP) systems for the determination of metals. The following will be performed in support of these requirements:

- Documentation of standard response
- Correlation coefficient monitoring

The AA system utilized for direct aspiration technique analysis will be initially calibrated with a calibration blank and five calibration standards. The standard concentrations will be determined as follows. One standard will be at a concentration near, but above, the MDL. The other concentrations will correspond to the expected range of concentrations found in the actual samples. This five-point calibration must be performed daily.

The AA system utilized for graphite furnace technique analysis will be initially calibrated with a calibration blank and three calibration standards. The standard concentrations will be determined as follows. One standard will be at a concentration at the Contract Required Detection Limit (CRDL). The other concentrations will correspond to the expected range of concentrations found in the actual samples. This five-point calibration must be performed daily.

For AA systems, the calibration standards will be prepared fresh each time an analysis is to be performed and discarded after use. The standards contain the same reagents at the same concentrations as will result in the samples following preparation.

The ICP system will be calibrated initially with a calibration blank and one calibration standard. This calibration must be performed daily. In addition, ICP systems must undergo quarterly linearity checks.

#### Correlation Coefficient Calculation

The data points of the blank and the five calibration standards will be utilized to calculate the slope, the intercept, and the correlation coefficient of the best fit line. An acceptable correlation coefficient must be achieved before sample analysis may begin. An acceptable correlation coefficient will be  $>0.995$  for AA analyses and  $>0.995$  for ICP analysis.

#### Calibration Verification

The initial calibration curve will be verified on each working day by the measurement of one mid-range calibration standard. The calibration verification acceptance criterion will be as follows:

- ICEP/GFAA – 90 to 110 percent of true value
- Cold Vapor AA – 80 to 120 percent of true value

When measurements exceed the control limits, the analysis will be terminated, the problem corrected, the instrument recalibrated, and the calibration reverified.

#### **7.2.6 System Calibration Procedure for Inorganic Analyses**

This section outlines the requirements that will be used for calibration of colorimetric systems for analyses of inorganic parameters. The following will be performed in support of these requirements:

- Documentation of standard response
- Correlation coefficient monitoring

The system will be initially calibrated with a blank and five calibration standards. Standard concentrations will be at a concentration near, but above, the MDL with additional concentrations corresponding to the expected range of concentrations found in actual samples. Standards contain the same reagents at the same concentrations as will be present in samples following preparation.

##### Correlation Coefficient Calculation

Data points of the blank and five calibration standards will be utilized to calculate slope, intercept, and correlation coefficient of a best fit line. An acceptable correlation coefficient must be achieved before sample analysis may begin. An acceptable correlation coefficient will be  $>0.995$  for all systems.

##### Calibration Verification

The initial calibration curve will be verified on each working day by the measurement of two calibration standards. One standard will be at a concentration near the low end of the calibration curve and one standard will be at the high end. The acceptance criteria for recovery of verification standards will be within 15 percent of the expected recovery for cyanide analyses and 10 percent of the expected recovery for other inorganic analyses. When measurements exceed control limits, analysis will be terminated, the problem will be corrected, the instrument will be recalibrated, and calibration will be reverified.

#### **7.2.7 Periodic Calibration**

Periodic calibration must be performed on equipment required in analyses but not routinely calibrated as part of the analytical methodology. Equipment that falls within this category includes ovens, refrigerators, and balances. The calibration will be recorded either on specified forms or in bound notebooks. Discussed below are the equipment, the calibration performed, and the frequency at which the calibration must be performed.

- Balances will be calibrated weekly with class S weights.
- The pH meter will be calibrated daily with pH 4 and 7 buffer solutions and checked with pH 10 buffer solution.
- The temperatures of the refrigerators will be recorded daily.
- All liquid in glass thermometers will be calibrated annually with the N.B.S. certified thermometer. Dial thermometers will be calibrated quarterly.

- The N.B.S. Certified Thermometer will be checked annually at the ice point.

The following equipment must maintain the following temperatures:

- Sample Storage and Refrigerators – within 2 degrees of 4 degrees Celsius
- Water Bath, Mercury – within 2 degrees of 95 degrees Celsius



## **8.0 ANALYTICAL PROCEDURES**

This next section discusses analytical procedures.

### **8.1 Field Analysis**

Field samples will be collected and analyzed for PCBs using immunoassay analysis. Detection limits for the field screening will be 1 mg/kg and 10 mg/kg. Field screening will be performed as per the methods/procedures provided by the manufacturer and/or distributor of the field testing kits.

The HNu PI-101, and O<sub>2</sub>/LEL meters will be used to analyze ambient air for health and safety monitoring, as well as to screen soil during the soil sampling. The HNu PI-101 detects total organic vapor. The O<sub>2</sub>/LEL meter detects explosive gases that may be present (i.e., methane). The MiniRam Model PDM-3 will be used to monitor total dust in the work areas. These instruments will be operated in accordance with the manufacturer's instructions.

The pH, temperature, specific conductivity and turbidity of aqueous samples also will be measured in the field. These analyses will be obtained in accordance with "Handbook for Sampling and Sample Preservation of Water and Wastewater," September 1982, EPA/600/4-82-029.

### **8.2 Laboratory Analysis**

The samples that will be collected during the investigation will be analyzed for constituents listed in Table 8-1. Parameters will be analyzed using USEPA methods as noted in Table 8-1. Compounds and the corresponding method performance limits also are listed in Table 8-1.

## **9.0 DATA REDUCTION, VALIDATION AND REPORTING**

The following section presents data reduction, validation, and reporting procedures.

### **9.1 Field Data Procedures**

Data validation practices as described by "Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses," USEPA, June 1988, and "Laboratory Data Validation Functional Guidelines for Evaluating Organic Analyses - Draft," USEPA, June 1991 will be followed to insure that raw data are not altered and that an audit trail is developed for those data which require reduction.

The documentation of sample collection will include the use of bound field log books in which all information on sample collection will be entered in indelible ink. Appropriate information will be entered to reconstruct the sampling event, including site name (top of each page), sample identification, brief description of sample, date and time of collection, sampling methodology, field measurements and observations, and sampler's initials (bottom of each page, and dated).

A rigorous data control program will insure that all documents for the investigations are accounted for when they are completed. Accountable documents include items such as log books, field data records, correspondence, chain-of-custody records, analytical reports, data packages, photographs, computer disks, and reports. The project manager will be responsible for maintaining a project file in which all accountable documents will be inventoried. The project records will be retained for a period of three years after project close-out; then the files will be forwarded to the Navy.

All the field data, such as those generated during field measurements, observations and field instrument calibrations, will be entered directly into a bound field notebook. Each project team member will be responsible for proofing all data transfers made, and the Project Manager or his designee will proof at least ten percent of all data transfers.

### **9.2 Laboratory Data Procedures**

The following procedures summarize the practices routinely used by laboratory staff for data reduction, validation, and reporting. Numerical analyses, including manual calculations, will be documented and subjected to quality control review. Records of numerical analyses must be legible and complete enough to permit reconstruction of the work by a qualified individual other than the originator.

#### **9.2.1 Laboratory Data Validation**

Data validation begins with data reduction and continues through to the reporting of data.

Data processing will be checked by an individual other than the analyst who performed the data processing. The checker will review the data for the following:

- Utilization of the proper equations
- Correctness of numerical input
- Correctness of computations
- Correct interpretation of raw data (chromatographs, strip charts, etc.)

The checking process will be sufficiently thorough enough to verify the results.

All entries made in benchbooks, data sheets, computation sheets, input sheets, etc. will be made in ink. No entry will be rendered unreadable.

### **9.2.2 Analytical Reports**

The items listed below will be required of analytical reports.

- Data will be presented in a tabular format.
- Analytical reports will be approved by appropriate laboratory personnel.
- The following information will be included on the report: client name and address, report date, sample date, analysis dates, number of samples, purchase order number, project number, and project type. All pages must be numbered.
- The sample numbers and corresponding laboratory numbers will be identified.
- The parameters analyzed, report units, and values will be identified.
- Method, trip, and field blank results will be reported.
- Matrix spike, matrix spike duplicate, and replicate recoveries will be reported.
- Calibration summaries will be reported.
- Surrogate recoveries will be reported.
- Holding times and sample analysis dates will be reported.
- The detection limit of the procedure will be identified.
- Consistent significant figures will be used.
- Referenced footnotes will be used when applicable.
- A letter of transmittal will accompany the report if any anomalies are associated with the data.

### **9.3 Independent (Third Party) Data Validation**

Review of all pertinent analytical data will be performed by Baker personnel and an independent third party data validator.

A preliminary review will be performed by the Project Manager or designee to verify that all necessary paperwork (e.g., chain-of-custodies, traffic reports, analytical reports, and laboratory personnel signatures) and deliverables are present. A detailed and independent data validation will be performed by a data validation subcontractor to verify the qualitative and quantitative reliability of the data presented and adherence to stated analytical protocols. This review will include a detailed review and interpretation of all data generated by the laboratory for Level III or IV deliverables. The primary tools which will be used by experienced data validation personnel will be analytical method operating

practices, statements of work (for CLP), guidance documents, established criteria, and professional judgment.

During the data review, a data support documentation package will be prepared which will provide the back-up information that will accompany all qualifying statements present in the quality assurance review.

## **10.0 INTERNAL QUALITY CONTROL CHECKS**

The following section describes internal quality control checks.

### **10.1 Field Quality Control Checks**

Four types of field quality assurance/quality control samples will be submitted to the laboratory: trip blanks, equipment rinsates, field blanks, and field duplicates. The results from the field quality control samples will be used by the data validator to determine the overall quality of the data. A breakdown by type of sample with which the QA/QC samples will be submitted to the laboratories is given in Table 10-1. A summary of the number of environmental and QA/QC samples to be submitted for analysis is given in the FSP.

#### **Field Blanks**

Field blanks consist of the source water used in decontamination, steam cleaning, and drilling. At a minimum, one field blank from each vent and each source of water must be collected and analyzed for the same parameters as the related samples. Organic-free deionized water is taken to the field in sealed containers and poured into the appropriate sample containers at predesignated locations. This will be done to determine if any contaminants present in the area may have an affect on the sample integrity.

#### **Trip Blank**

Analysis of trip blanks will be performed to monitor possible contamination during shipment and collection of samples. Trip blanks are initiated in the laboratory prior to the shipping of sample packs. A corresponding trip blank will be prepared for each set of samples to be analyzed for volatile organic compounds.

Trip blank samples will be prepared by adding four drops of concentrated hydrochloric acid and then filling the container with organic-free deionized water (ASTM Type II). The trip blanks accompany the samples through shipment of sample containers to the sample site, sample collection, shipment to the laboratory, and storage of the samples.

If the analyses indicate contamination of the trip blank, the sample sources may be resampled. If the extent and nature of the contamination does not warrant such actions, the data will be accepted as valid.

#### **Field Duplicates**

Duplicates for soil samples are collected at the same time as the specific environmental samples. All samples, except VOCs, are homogenized and split. Volatiles are not mixed, but select segments of the soil are taken from the length of the core and placed in 4-ounce glass jars. Cores may be sealed and shipped to the laboratory for subsampling if the project deems this appropriate. The duplicate for water samples should be collected simultaneously. Field duplicates should be collected at a frequency of 10% per sample matrix for Levels III and IV. All the duplicates should be sent to the primary laboratory responsible for analysis. The same samples used for field duplicates shall be split by the laboratory and used by the laboratory as the laboratory duplicate or matrix spike. This means that for the duplicate sample, there will be analyses of the normal sample, the field duplicate, and the laboratory matrix spike/duplicate.

## **Equipment Rinsates**

Equipment rinsates are the final organic-free deionized water rinse from equipment cleaning collected daily during a sampling event. Initially, samples from every other day should be analyzed. If analytes pertinent to the project are found in the rinsate, the remaining samples must be analyzed. The results of the blanks will be used to flag or assess levels of analytes in the samples. This comparison is made during validation. The rinsates are analyzed for the same parameters as the related samples.

## **Field Matrix Spike/Matrix Spike Duplicates**

Field Matrix Spike/Matrix Spike Duplicates (MS/MSD) are samples collected in the field at the time regular investigation samples are collected. They are analyzed by the laboratory as quality control samples, the same as field duplicates. MS/MSDs are collected as separate samples, listed on the chain-of-custody as such, and submitted to the laboratory for analysis of the same parameters as regular investigation samples. MS/MSDs are collected at a frequency of 5 % per sample matrix.

### **10.2 Laboratory Quality Control Checks**

This section provides descriptions of the laboratory quality control checks.

#### **Method Blank**

Analysis of method blanks will be performed to verify that method interferences caused by contamination in reagents, glassware, solvents, etc. are minimized and known.

Method blanks will be initiated by the analyst prior to the preparation and/or analysis of the sample set. A method blank consists of a volume of organic-free deionized water equal to the sample volume which is carried through the entire analytical procedure. For solid samples to be analyzed by GC/MS, the method blank consists of a purified solid matrix approximately equal to the sample weight. A method blank will be analyzed with each set of samples or, at the very least, daily. If the analytical data of the method blank indicates excessive contamination, the source of contaminant will be determined. The samples may be re-analyzed or the data may be processed "as is" depending upon the nature and extent of the contamination.

#### **Replicate Sample Analysis**

Replicate sample analysis will be performed to demonstrate the precision of an analysis. An interlaboratory replicate sample is initiated by the analyst prior to sample preparation and carried through the entire analytical procedure. The frequency of interlaboratory replicate analysis for each analyte is summarized in Table 10-2.

#### **Spike Analysis**

Spike analysis will be performed to demonstrate the accuracy of an analysis. The analyst initiates the spike prior to sample preparation and analysis by adding a known amount of analyte(s) to a sample. The spike sample is carried through the entire analytical procedure. The frequency of spike analysis for each analyte(s) is summarized in Table 10-2.

## **Surrogate Standards**

Surrogate standard analysis will be performed to monitor the preparation and analyses of samples. All samples and blanks analyzed by GC/MS are fortified with a surrogate spiking solution prior to extraction or purging.

## **Internal Standards**

Internal standard analyses will be performed to monitor system stability. Prior to injection or purging, internal standards are added to all blanks and samples analyzed by GC/MS (refer to Section 5.1.1.).

## **Matrix Spikes and Matrix Spike Duplicates**

A matrix spike is an aliquot of a matrix (water or soil) fortified (spiked) with known quantities of specific compounds and subjected to the entire analytical procedure in order to indicate the appropriateness of the method for the matrix by measuring recovery. A matrix spike duplicate is a second aliquot of the same matrix as the matrix spike that is spiked in order to determine the precision of the method. A matrix spike and matrix spike duplicate will be performed at a frequency of 1 per 20 samples for organics.

### **10.3 Laboratory Control Limits**

Control limits will be established for QC checks (spikes, duplicates, blanks, etc.). CLP control limits for surrogate standards spikes, and duplicates associated with GC/MS analyses and pesticides/PCB analyses. Control limits for spikes, duplicates, and reference samples will be determined internally through statistical analysis.

Whenever an out-of-control situation occurs, the cause is determined. Any needed corrective actions must be taken.

## **Method Blanks**

For metals analyses, the criteria below are used for method blank analysis.

- If the concentration of the method blank is less than or equal to the detection level, no correction of sample results is performed.
- If the concentration of the blank is above the detection level for any group of samples associated with a particular blank, the concentration of the sample with the least concentrated analyte must be ten times the blank concentration. Otherwise, all samples associated with the blank and less than ten times the blank concentration must be redigested (reprepared) and reanalyzed, if possible. If the affected samples cannot be reprepared and reanalyzed within method holding times, the flagged sample result and the blank result are both to be reported. The sample value is not corrected for the blank value.

For GC/MS, GC analyses, the criteria below are used for method blank analysis:

- A method blank for volatiles analysis must contain no greater than five times the detection limit of common laboratory solvents (common laboratory solvents are: methylene chloride, acetone, toluene, 2-butanone, and chloroform).
- A method blank for semivolatiles analysis must contain no greater than five times the detection limit of common phthalate esters.
- For all other compounds not listed above, the method blank must contain less than the detection limit of any single compound. If a method blank exceeds the criteria, the analytical system is considered to be out of control. The source of the contamination is investigated and appropriate corrective measures are taken and documented before sample analysis proceeds. All samples processed with a method blank that is out of control (i.e., contaminated), are reextracted/repurged and reanalyzed, when possible. If the affected samples cannot be reextracted/repurged and reanalyzed within method holding times, the flagged sample result and the blank result are both to be reported. The sample value is not corrected for the blank value.
- No positive result for pesticides/PCBs should be reported unless the concentration of the compound exceeds five times the amount in the blank.
- A method blank for pesticides/PCBs must contain no greater than five times the detection limit for any pesticides/PCBs.

#### **Surrogate Standards**

For method blank surrogate standard analysis, corrective action will be taken if any one of the conditions below exist.

- Recovery of any one surrogate compound in the volatile fraction is outside the required surrogate standard recovery limit.
- Recovery of any one surrogate compound in the semivolatile fraction is outside surrogate standard recovery limits.

Corrective action will include steps listed below:

- A check of: the calculations for errors; the internal standard and surrogate spiking solutions for degradation, contamination, etc.; and instrument performance.
- Recalculation or reinjection/repurging of the blank or extract if the above corrective actions fail to solve the problem.
- Reextraction and reanalysis of the blank. For sample surrogate standard analysis, corrective action will be taken if any one of the following conditions exist:
  - Recovery of any one surrogate compounds in the volatile fraction is outside the surrogate spike recovery limits;



- Recovery of any one surrogate compound in either semivolatile fraction is below ten percent; or
- Recoveries of two or more surrogate compounds in either semivolatile fraction are outside surrogate spike recovery limits.

Corrective action will include the steps listed below.

- A check of: the calculations for errors; of the internal standard and surrogate spiking solutions for degradation, contamination, etc.; and of instrument performance.
- Recalculating or reanalysis the sample or extract if the above corrective action fails to solve the problem.
- Reextraction and reanalysis of the sample if none of the above are a problem.

## **11.0 PREVENTIVE MAINTENANCE**

The following section outlines preventative maintenance.

### **11.1 Field Maintenance**

The MiniRam (RDM-3), the O<sub>2</sub>/LEL meter, and the HNu PI-101 are to be used in site characterization and will be maintained as described by the manufacturer's instructions. The pH, specific conductance and turbidity meters to be used during sampling will be maintained according to Baker's Standard Operating Procedure (SOP) F201. A full set of SOPs will be maintained in the field trailer.

### **11.2 Laboratory Maintenance**

Preventive maintenance is an organized program of actions to prevent instruments and equipment from failing during use and to maintain proper performance of equipment and instruments. A comprehensive preventive maintenance program is implemented to increase the reliability of the measurement system. The preventive maintenance program will address the following:

- Schedules of important preventive maintenance tasks that are carried out to minimize downtime.
- Lists of critical spare parts that are available to minimize downtime.

The laboratory maintains histories, in instrument/equipment logs, of all major equipment. Trouble shooting, maintenance, and spare parts inventory will be recorded in the logs. Instruments and equipment will be maintained periodically in accordance with procedures described in individual analytical methods, manufacturer's recommendation, and/or service contracts.

The modern analytical laboratory depends heavily upon instrumentation and equipment; therefore, cleaning and preventive maintenance are primary considerations in the sustained production of satisfactory data. Specific requirements for proper care of laboratory instrumentation and equipment are contained in the manufacturer's instructions; however, some general guidelines are considered, and are listed below.

- Special precautions must be taken to avoid spillage of corrosive chemicals on or around equipment and instrumentation not only to extend the life of the item, but also to eliminate contamination.
- Where available, covers must be placed on instrumentation when not in use.
- Instrument parts must be cleaned as required (i.e., mirrors, probes, detector cells).

## **12.0 DATA MEASUREMENT ASSESSMENT PROCEDURES**

The following section outlines data measurement assessment procedures.

### **12.1 Overall Project Assessment**

Overall data quality will be assessed by a thorough understanding of the data quality objectives. By maintaining thorough documentation of all decisions made during each phase of sampling, performing field and laboratory audits, thoroughly reviewing the analytical data as they are generated by the laboratory, and providing appropriate feedback as problems arise in the field or at the laboratory, data accuracy, precision, and completeness will be closely monitored.

### **12.2 Field Quality Assessment**

To assure that all field data are collected accurately and correctly, specific written instructions will be issued to all personnel involved in field data acquisition by the Project Manager. The Project Manager will perform field audit(s) during the investigation to document that the appropriate procedures are being followed with respect to sample (and blank) collection. These audits will include a thorough review of the field books used by the project personnel to insure that all tasks were performed as specified in the instructions. The field audits will necessarily enable the data quality to be assessed with regard to the field operations.

The evaluation (data review) of field blanks, and other field QC samples will provide definitive indications of the data quality. If a problem that can be isolated arises, corrective actions can be instituted for future field efforts.

### **12.3 Laboratory Data Quality Assessment**

As part of the analytical QA/QC program, the laboratory applies precision and accuracy criteria for each parameter that is analyzed. When analysis of a sample set is completed, QC data generated will be reviewed and evaluated to ensure acceptance criteria are met. These criteria will be method and matrix specific.

QA/QC data review is based on the following criteria:

- **Method Blank Evaluation** - The method blank results will be evaluated for high readings characteristic of background contamination. If high blank values are observed, laboratory glassware and reagents are checked for contamination and the analysis of future samples halted until the system can be brought under control. A high background is defined as a background value sufficient to result in a difference in the sample values, if not corrected, greater than or equal to the smallest significant digit known to be valid. A method blank must contain no greater than two times the parameter detection limit for most parameters.
- **Trip Blank Evaluation** - Trip blank results will be evaluated for high readings similar to the method blanks described above. If high trip blank readings are encountered (i.e. a value sufficient to result in a difference in sample values, if not corrected, greater than or equal to the smallest significant digit known to be valid), procedures for sample collection, shipment, and laboratory analysis are reviewed. If both the method and the trip blanks exhibit significant background contamination, the source

of contamination is probably within the laboratory. Ambient air in the laboratory and reagents will be checked as possible sources of contamination.

- Standard Calibration Curve Verification – The calibration curve or midpoint calibration standard (check standard) will be evaluated daily to determine curve linearity through its full range and that sample values are within the range defined by the low and high standards. If the curve is not linear, sample values are corrected. If average response factors are used to calculate sample concentrations, these factors are verified on a daily basis. Verification of calibration curves and response factors will be accomplished when the evaluated response for any parameter varies from the calibrated response by less than ranges specified in Section 7.0.
- Duplicate Sample Analyses – Duplicate sample analyses will be used to determine the precision of the analytical method for the sample matrix. Two types of duplicate samples will be analyzed for this project, field, and laboratory. Duplicate results will be used to calculate precision as defined by the relative percent difference (RPD). If laboratory duplicate values exceeds the control limit, the sample set may be reanalyzed for the parameter in question. Precision limits will be updated periodically following review of data.
- Reference Sample Analyses – The results of reference sample analysis will be compared with true values, and the percent recovery of the reference sample will be calculated. If correction is required (excessive or inadequate percent recovery), the reference sample must be reanalyzed to demonstrate that the corrective action has been successful.
- Surrogate Standard Analyses – Surrogate standard determinations will be performed on all samples and blanks for GC/MS analyses. All samples and blanks are fortified with surrogate spiking compounds before purging or extraction to monitor preparation and analysis of samples. Recoveries must meet specific criteria. If acceptance criteria are not met, corrective action must be taken to correct the problem and the affected sample must be reanalyzed.
- Matrix Spike Analyses – The observed recovery of spike versus theoretical spike recovery will be used to calculate accuracy as defined by the percent recovery. If the accuracy value exceeds the control limit for the given parameter, the appropriate laboratory personnel notified and corrective action will be taken before the sample set is reanalyzed for the parameter in question.

For completeness, it is expected that the methodology proposed for chemical characterization of the samples will meet QC acceptance criteria for at least 95 percent of all sample data. To ensure this completeness goal, data that does not meet the acceptance criteria will be recollected, reextracted, or reanalyzed, if necessary.

Data representativeness will be ensured through the use of appropriate analytical procedures, and analysis of samples performed within the allowed holding times.

Comparability is a qualitative characteristic of the data. By using standard methods for sampling and analyses, data generated in past or future investigations will be comparable with this investigation data.

### **13.0 CORRECTIVE ACTION**

Corrective action will be taken whenever a nonconformance occurs. A nonconformance will be defined as an event which is beyond the limits established for a particular operation by the plan. Nonconformances can occur in a number of activities. Such activities include sampling procedures, sample receipt, sample storage, sample analysis, data reporting, and computations.

The following personnel will be responsible for detecting and reporting nonconformances:

- Project Staff – during testing and preparation and verification of numerical analyses.
- Laboratory Staff – during the preparation for analyses, performance of analytical procedures, calibration of equipment, and quality control activities.

#### **13.1 Limits of Operation**

The limits of operation that are used to identify nonconformances will be established by the contents of the Work Plan, QAPP, and FSAP. Interlaboratory control limits produced by statistical analyses will also be considered as limits of operation.

#### **13.2 Corrective Action**

Nonconformances will be identified and communicated to Baker to avoid delays with respect to project schedules and prevent the submission of non-valid data. Documentation will include the following:

- Personnel identifying the nonconformance(s) will be identified.
- The nonconformance(s) will be described and communicated to the Baker Project Manager.
- For serious nonconformances, the site supervisor will have the authority to initiate corrective action.
- For less serious nonconformances, corrective action will be decided upon and signatures will be obtained prior to implementation of corrective action.
- All nonconformances and corrective actions will be documented and reside with the Baker Activity Coordinator. This documentation will be available to LANTDIV.
- All non-conformance from the approved Project Plans will be reported and documented in the RI/FS Report.

The Baker Project Manager and Activity Coordinator will be notified of laboratory or field nonconformances and corrective actions taken if:

- A nonconformance causes a delay in work beyond the schedule completion date.
- A nonconformance affects information already reported.
- A nonconformance affects the validity of the data.

If the nonconformance(s) are serious and corrective action cannot resolve the problem(s), NEESA Contract Representatives (NCRs) and the LANTDIV NTR may be notified by Baker.

#### **14.0 QUALITY ASSURANCE REPORTING PROCEDURES**

The Project Manager will be responsible for assessing the performance of measurement systems and data quality related to the field investigation. A written record will be maintained of: the results of laboratory QC reports and other periodic assessments of measurement, data accuracy, precision, and completeness; performance and system audits; and any significant QA problems and recommended solutions. Each deliverable will contain a QA/QC assessment section. Also, a QA/QC assessment will be performed any time a significant problem is identified.

The Project Manager will keep in contact with the LANTDIV NTR through informal, verbal reports during the project as well as through monthly progress reports.

## **TABLES**



**TABLE 5-1**

**DEFINITIONS OF DATA QUALITY INDICATORS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SITE 84/BUILDING 45 AREA  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA**

PRECISION. A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is expressed in terms of the standard deviation. Comparison of replicate values is best expressed as the relative percent difference (RPD). Various measures of precision exist depending upon the "prescribed similar conditions".
ACCURACY. The degree of agreement of a measurement (or an average of replicate measurements), X, with an accepted reference or true value, T, expressed as the difference between the two values, XT. Accuracy is a measure of the bias in a system.
REPRESENTATIVENESS. Expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental concern.
COMPLETENESS. A measure of the amount of the valid data obtained from the measurement system compared to the amount that was expected under "normal" conditions.
COMPARABILITY. Expresses the confidence with which one data set can be compared with another.
UNCERTAINTY. The likelihood of all types of errors associated with a particular decision.

**TABLE 6-1**

**SUMMARY OF AQUEOUS SAMPLE CONTAINER,  
PRESERVATIVE AND HOLDING TIME  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SITE 84/BUILDING 45 AREA  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA**

Parameter	Container	Preservation	Holding Time
TCL Volatiles	Two 40-ml vials with teflon septum caps	Cool, 4°C HCl pH <2	10 days (7 days if unpreserved)
TCL Semivolatiles	1-liter amber glass bottle with teflon caps	Cool, 4°C	5 days to extraction; 40 days from extraction to analysis
TCL Pesticides PCBs	1-liter amber glass bottle with teflon caps	Cool, 4°C	5 days to extraction; 40 days after extraction for analysis
TAL Metals	1-500 ml polyethylene bottle	HNO <sub>3</sub> pH<2	180 days; Mercury 28 days

**TABLE 6-2**

**SUMMARY OF SOIL SAMPLE CONTAINER,  
PRESERVATION AND HOLDING TIME  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SITE 84/BUILDING 45 AREA  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA**

Parameter	Container	Preservation	Holding Time
TCL Volatiles	One 4-ounce widemouth glass jars	Cool, 4°C	10 days
TCL Semivolatiles	One 8-ounce widemouth glass jar	Cool, 4°C	7 days to extraction; 40 days from extraction to analysis
TCL Pesticides PCBs	One 8-ounce widemouth glass jar	Cool, 4°C	7 days to extraction; 40 days after extraction for analysis
TAL Metals	One 8-ounce widemouth glass jar	Cool, 4°C	6 months; Mercury, 28 days
TCLP Metals	Two 8-ounce widemouth glass jar	Cool, 4°C	14 days to extraction
Corrosivity	One 4-ounce widemouth glass jar	Cool, 4°C	10 days
TPH	One 4-ounce widemouth glass jar	Cool, 4°C	28 days

TABLE 8-1

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Compound	Water CRQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Soil/Sediment CRQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
<b><u>Volatiles</u></b>			CLP/SOW
Chloromethane	10	10	
Bromomethane	10	10	
Vinyl Chloride	10	10	
Chloroethane	10	10	
Methylene Chloride	10	10	
Acetone	10	10	
Carbon Disulfide	10	10	
1,1-Dichloroethene	10	10	
1,1-Dichloroethane	10	10	
1,2-Dichloroethene (total)	10	10	
Chloroform	10	10	
1,2-Dichloroethane	10	10	
2-Butanone	10	10	
1,1,1-Trichloroethane	10	10	
Carbon Tetrachloride	10	10	
Bromodichloromethane	10	10	
1,2-Dichloropropane	10	10	
cis-1,3-Dichloropropene	10	10	
Trichloroethene	10	10	
Dibromochloromethane	10	10	
1,1,2-Trichloroethane	10	10	
Benzene	10	10	
trans-1,3-Dichloropropene	10	10	
Bromoform	10	10	
4-Methyl-2-pentanone	10	10	
2-Hexanone	10	10	
Tetrachloroethene	10	10	
Toluene	10	10	
1,1,2,2-Tetrachloroethane	10	10	
Chlorobenzene	10	10	
Ethylbenzene	10	10	
Styrene	10	10	
Xylenes (total)	10	10	

<sup>(1)</sup> Contract Required Quantitation Limit

<sup>(2)</sup> "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Compound	Water CRQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Soil/Sediment CRQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
<b><u>Semivolatiles</u></b>			CLP/SOW
Phenol	10	330	
bis(2-Chloroethyl) ether	10	330	
2-Chlorophenol	10	330	
1,3-Dichlorobenzene	10	330	
1,4-Dichlorobenzene	10	330	
Benzyl alcohol	10	330	
1,2-Dichlorobenzene	10	330	
2-Methylphenol	10	330	
bis(2-Chloroisopropyl)ether	10	330	
4-Methylphenol	10	330	
N-Nitroso-di-n-dipropylamine	10	330	
Hexachloroethane	10	330	
Nitrobenzene	10	330	
Isophorone	10	330	
2-Nitrophenol	10	330	
2,4-Dimethylphenol	10	330	
Benzoic acid	25	1600	
bis(2-Chloroethoxyl)methane	10	330	
2,4-Dichlorophenol	10	330	
1,2,4-Trichlorobenzene	10	330	
Naphthalene	10	330	
4-Chloroaniline	10	330	
Hexachlorobutadiene	10	330	
4-Chloro-3-methylphenol	10	330	
2-Methylnaphthalene	10	330	
Hexachlorocyclopentadiene	10	330	
2,4,6-Trichlorophenol	10	330	
2,4,5-Trichlorophenol	25	1600	
2-Chloronaphthalene	10	330	
2-Nitroaniline	25	1600	
Dimethylphthalate	10	330	
Acenaphthylene	10	330	

<sup>(1)</sup> Contract Required Quantitation Limit

<sup>(2)</sup> "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Compound	Water CRQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Soil/Sediment CRQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
2,6-Dinitrotoluene	10	330	CLP/SOW
3-Nitroaniline	25	1600	
Acenaphthene	10	330	
2,4-Dinitrophenol	25	1600	
4-Nitrophenol	25	1600	
Dibenzofuran	10	330	
2,4-Dinitrotoluene	10	330	
Diethylphthalate	10	330	
4-Chlorophenyl-phenyl ether	10	330	
Fluorene	10	330	
4-Nitroaniline	25	1600	
4,6-Dinitro-2-methylphenol	25	1600	
N-nitrosodiphenylamine	10	330	
4-Bromophenyl-phenylether	10	330	
Hexachlorobenzene	10	330	
Pentachlorophenol	25	1600	
Phenanthrene	10	330	
Anthracene	10	330	
Di-n-butylphthalate	10	330	
Fluoranthene	10	330	
Pyrene	10	330	
Butylbenzylphthalate	10	330	
3,3'-Dichlorobenzidine	10	660	
Benzo(a)anthracene	10	330	
Chrysene	10	330	
bis(2-Ethylhexyl)phthalate	10	330	
Di-n-octylphthalate	10	330	
Benzo(b)fluoranthene	10	330	
Benzo(k)fluoranthene	10	330	
Benzo(a)pyrene	10	330	
Indeno(1,2,3-cd)pyrene	10	330	
Dibenz(a,h)anthracene	10	330	
Benzo(g,h,i)perylene	10	330	

<sup>(1)</sup> Contract Required Quantitation Limit

<sup>(2)</sup> "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Compound	Water CRQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Soil/Sediment CRQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
<b><u>Pesticides/PCBs</u></b>			CLP/SOW
alpha-BHC	0.05	8.0	
beta-BHC	0.05	8.0	
delta-BHC	0.05	8.0	
gamma-BHC (Lindane)	0.05	8.0	
Heptachlor	0.05	8.0	
Aldrin	0.05	8.0	
Heptachlor epoxide	0.05	8.0	
Endosulfan I	0.05	8.0	
Dieldrin	0.10	16.0	
4,4'-DDE	0.10	16.0	
Endrin	0.10	16.0	
Endosulfan II	0.10	16.0	
4,4'-DDD	0.10	16.0	
Endosulfan sulfate	0.10	16.0	
4,4'-DDT	0.10	16.0	
Methoxychlor	0.5	80.0	
Endrin ketone	0.10	16.0	
alpha-Chlordane	0.5	80.0	
gamma-Chlordane	0.5	80.0	
Toxaphene	5.0	160.0	
Aroclor-1016	1.0	80.0	
Aroclor-1221	2.0	80.0	
Aroclor-1232	1.0	80.0	
Aroclor-1242	1.0	80.0	
Aroclor-1248	1.0	80.0	
Aroclor-1254	1.0	160.0	
Aroclor-1260	1.0	160.0	

<sup>(1)</sup> Contract Required Quantitation Limit

<sup>(2)</sup> "Statement of Work for Organic Analysis," USEPA Contract Laboratory Program, OLM01.8.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Analyte	Method Number <sup>(1)</sup>	CRDL <sup>(2)</sup> ( $\mu\text{g/L}$ )	Method Description
<b>Metals</b>			
Aluminum	200.7	200	Inductively Coupled Plasma
Antimony	200.7 204.2	60	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Arsenic	200.7 206.2	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Barium	200.7	200	Inductively Coupled Plasma
Beryllium	200.7 210.2	5	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Cadmium	200.7 213.2	5	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Calcium	200.7 215.1	5000	Inductively Coupled Plasma Atomic Absorption, Direct Aspiration
Chromium	200.7 218.2	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Cobalt	200.7	50	Inductively Coupled Plasma
Copper	200.7	25	Inductively Coupled Plasma
Iron	200.7	100	Inductively Coupled Plasma
Lead	200.7 239.2	3	Inductively Coupled Plasma Atomic Absorption, Furnace Technique

(1) Methods taken from "Statement of Work for Inorganic Analysis," USEPA Contract Laboratory Program, ILM03.0, March 1990.

(2) Contract Required Detection Limit.

(3) Extraction method for arsenic, lead, selenium, and thallium taken from USEPA Method 3020, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

(4) Extraction method for all other metals taken from USEPA Method 3010, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.



TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Analyte	Method Number <sup>(1)</sup>	CRDL <sup>(2)</sup> ( $\mu\text{g/L}$ )	Method Description
Magnesium	200.7	5000	Inductively Coupled Plasma Atomic Absorption, Direct Aspiration
	242.1		
Manganese	200.7	15	Inductively Coupled Plasma
Mercury	245.1	0.2	Water by manual cold vapor technique Water by automated cold vapor technique Soil/sediment by manual cold vapor technique
	245.2		
	245.5		
Nickel	200.7	40	Inductively Coupled Plasma
Potassium	200.7	5000	Inductively Coupled Plasma Atomic Absorption, Direct Aspiration
	258.1		
Selenium	200.7	5	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
	270.2		
Silver	200.7	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
	272.2		
Sodium	200.7	5000	Inductively Coupled Plasma Atomic Absorption, Direct Aspiration
	273.1		
Thallium	200.7	10	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
	279.2		
Vanadium	200.7	50	Inductively Coupled Plasma
Zinc	200.7	20	Inductively Coupled Plasma

(1) Methods taken from "Statement of Work for Inorganic Analysis," USEPA Contract Laboratory Program, ILM03.0, March 1990.

(2) Contract Required Detection Limit.

(3) Extraction method for arsenic, lead, selenium, and thallium taken from USEPA Method 3020, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

(4) Extraction method for all other metals taken from USEPA Method 3010, "Test Methods for Evaluating Solid Waste," USEPA, November 1986, 3rd Edition.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Parameter	Aqueous PQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Solid PQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
<b><u>TCLP Volatiles</u></b>			EPA Method 3550/ EPA Method 8260
Benzene	5	10	
Carbon Tetrachloride	5	5	
Chloroform	5	5	
1,2-Dichloroethane	5	5	
1,1-Dichloroethylene	5	5	
Methyl ethyl ketone	NA	NA	
Tetrachloroethylene	5	5	
Trichloroethylene	5	5	
Vinyl Chloride	10	10	
<b><u>TCLP Semivolatiles</u></b>			EPA Method 3550/ EPA Method 8270
o-Cresol	10	660	
m-Cresol	10	660	
p-Cresol	10	660	
Cresol	10	660	
1,4-Dichlorobenzene	10	660	
2,4-Dinitrotoluene	10	660	
Hexachlorobenzene	10	660	
Hexachlorobutadiene	10	660	
Hexachloroethane	10	660	
Nitrobenzene	10	660	
Pentachlorophenol	50	3300	
Pyridine	50	660	
2,4,5-Trichlorophenol	10	660	
2,4,6-Trichlorophenol	10	660	

<sup>(1)</sup> Practical Quantitation Limit, taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.

Note: These methods will be used to analyze the Toxicity Characteristic Leaching Procedure (TCLP) extract. The extract will be prepared using Method 1311, described in "Hazardous Waste Management Systems; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52FR 26886.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Parameter	Aqueous PQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Solid PQL <sup>(1)</sup> ( $\mu\text{g/kg}$ )	Method
<b><u>TCLP Pesticides</u></b>			EPA Method 3550/ EPA Method 8080
Chlordane	0.14	9.4	
Endrin	0.06	4.0	
Heptachlor (and its hydroxide)	0.03	2.0	
Lindane	0.04	2.7	
Methoxychlor	1.8	120	
Toxaphene	2.4	160	
<b><u>TCLP Herbicides</u></b>			EPA Method 8151
2,4-D	12	240	
2,4,5-TP Silvex	1.7	34	

Analyte	Water PQL <sup>(1)</sup> ( $\mu\text{g/L}$ )	Soil PQL <sup>(1)</sup> ( $\text{mg/kg}$ )	Method	Method Description
<b><u>TCLP Metals</u></b>				
Arsenic	10	30	6010 7060	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Barium	20	1	6010	Inductively Coupled Plasma
Cadmium	1	2	6010 7131	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Chromium	20	4	6010 7191	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Lead	10	2	6010 7421	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Mercury	2	0.002	7470	Water by manual cold vapor technique Water by automated cold vapor technique
Selenium	20	40	6010 7740	Inductively Coupled Plasma Atomic Absorption, Furnace Technique
Silver	2	4	6010 7760	Inductively Coupled Plasma Atomic Absorption, Furnace Technique

<sup>(1)</sup> Practical Quantitation Limit, taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.  
 Note: These methods will be used to analyze the Toxicity Characteristic Leading Procedure (TCLP) extract. The extract will be prepared using Method 1311, described in "Hazardous Waste Management System; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions; Final Rule," USEPA, 52FR 26886.

TABLE 8-1 (Continued)

**METHOD PERFORMANCE LIMITS  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE, CAMP LEJEUNE, NORTH CAROLINA**

Parameter	Aqueous Performance Limit	Solid Performance Limit	Method
<b><u>RCRA</u></b>			
pH/Corrosivity	NA <sup>(1)</sup>	NA <sup>(1)</sup>	SW-846 9010
Ignitability	NA <sup>(1)</sup>	NA <sup>(1)</sup>	SW-846 1010
Reactive Cyanide	10 mg/L <sup>(1)</sup>	10 mg/L <sup>(1)</sup>	SW-846 9012
Reactive Sulfide	50 mg/L <sup>(1)</sup>	50 mg/kg <sup>(1)</sup>	SW-846 9030
<b><u>Engineering Parameters</u></b>			
Total Organic Carbon (TOC)	NA <sup>(2)</sup>	NA <sup>(2)</sup>	EPA 415.1
Particle Size Distribution	NA	NA	ASTM D 422-63

<sup>(1)</sup> Practical Quantitation Limit taken from "Test Methods for Evaluating Solid Waste," USEPA, November 1986.

<sup>(2)</sup> Method detection limit taken from "Methods for Chemical Analysis of Water and Wastes," USEPA, 1979, Revised March 1983.

NA = Not Applicable

TABLE 10-1

**QA/QC SAMPLE FREQUENCY  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SITE 84/BUILDING 45 AREA  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA**

Type of Sample	Metal	Organic
Trip Blank (for volatiles only)	NA <sup>(1)</sup>	One per cooler or one per shipping day
Equipment Rinsate <sup>(2)</sup>	One per day	One per day
Field Blank	One per source per event <sup>(3)</sup>	
Field Duplicate <sup>(4)</sup>	10%	10%
Field Matrix Spike/Matrix Spike Duplicate	5%	5%

(1) Not Applicable.

(2) Samples are collected daily; however, only samples from every other day are analyzed. Other samples are held and analyzed only if evidence of contamination exists.

(3) Source water includes water used in decontamination, steam cleaning, and drilling.

(4) The duplicate must be taken from the sample which will become the laboratory matrix spike/matrix spike duplicate for organics or for the sample used as a duplicate in inorganic analysis.

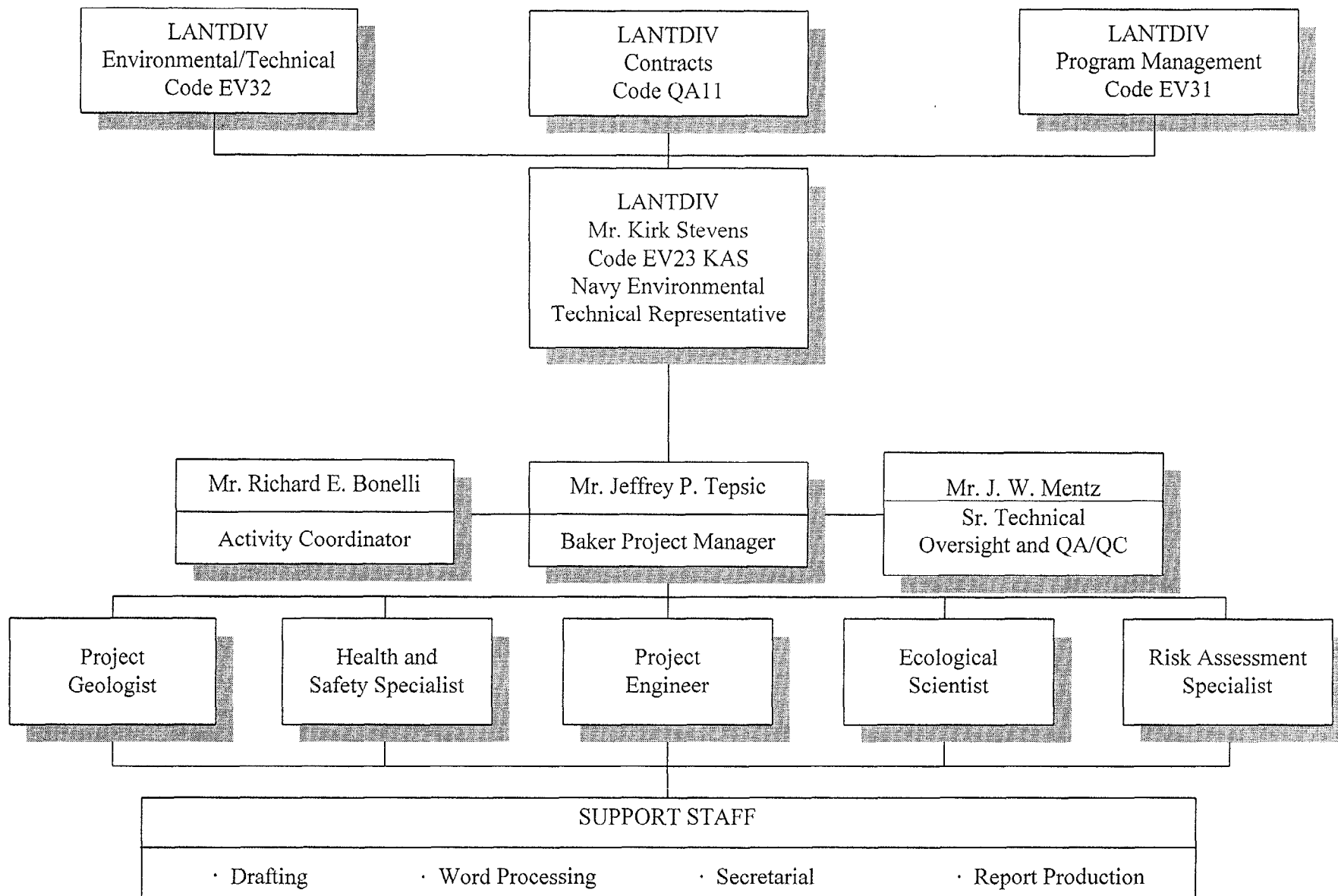
**TABLE 10-2**

**QC ANALYSIS FREQUENCY  
REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
SITE 84/BUILDING 45 AREA  
CTO-0139 (CLEAN II)  
MARINE CORPS BASE CAMP LEJEUNE, NORTH CAROLINA**

<b>Parameter</b>	<b>Replicate</b>	<b>Spike</b>
<b>Organic</b>		
All analyses by GC/MS	5%	5%
All analyses by GC	5%	5%
<b>Metals</b>		
Liquids by flame AA or ICP	5%	5%
Solids by flame AA or ICP	5%	10%
All analyses by furnace AA	5%	10%

## **FIGURES**

**FIGURE 4-1**  
**PROJECT ORGANIZATION**





**FINAL**

**REMEDIAL INVESTIGATION/FEASIBILITY STUDY  
HEALTH AND SAFETY PLAN  
SITE 84/BUILDING 45 AREA  
MCB CAMP LEJEUNE, NORTH CAROLINA**

**CONTRACT TASK ORDER 0139 (CLEAN II)**

**JUNE 2001**

*Prepared For:*

**DEPARTMENT OF THE NAVY  
ATLANTIC DIVISION  
NAVAL FACILITIES  
ENGINEERING COMMAND**  
*Norfolk, Virginia*

*Under the:*

**LANTDIV CLEAN Program  
Contract N62470-95-D-6007**

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## TABLE OF CONTENTS

	<u>Page</u>
<b>1.0 INTRODUCTION.....</b>	<b>1-1</b>
1.1 Purpose and Requirements .....	1-1
1.2 Site 84 Location, Description and History .....	1-1
1.2.1 Site Description .....	1-1
1.2.2 Site Topography and Drainage .....	1-2
1.2.3 Site History .....	1-2
1.2.4 Previous Investigations .....	1-2
1.3 Scope of Work .....	1-2
1.4 References .....	1-3
<b>2.0 RESPONSIBILITIES.....</b>	<b>2-1</b>
<b>3.0 SITE HAZARDS CHARACTERIZATION .....</b>	<b>3-1</b>
3.1 Hazard Analysis by Task.....	3-1
3.1.1 Monitoring Well Installation .....	3-1
3.1.2 Monitoring Well Development .....	3-2
3.1.3 Groundwater Sampling .....	3-2
3.1.4 Surface Soil Sampling.....	3-2
3.1.5 Subsurface Soil Boring-Sampling .....	3-3
3.1.6 Equipment Decontamination.....	3-3
3.2 Physical Hazards.....	3-3
3.2.1 Slip, Trip and Fall.....	3-4
3.2.2 Walking and Working Surfaces .....	3-4
3.2.3 Thermal Stress.....	3-4
3.2.4 Noise .....	3-4
3.2.5 Electrical Safe Works.....	3-5
3.2.6 Flammable or Combustible Materials .....	3-5
3.2.7 Underground and Overhead Utility Hazards.....	3-5
3.2.8 Heavy Equipment.....	3-6
3.3 Chemical Hazards .....	3-7
3.3.1 PCBs .....	3-7
3.3.2 Diesel Fuel.....	3-7
3.4 Environmental Hazards.....	3-8
3.4.1 Hazardous Flora .....	3-8
3.4.2 Hazardous Fauna.....	3-8
<b>4.0 SITE CONTROL.....</b>	<b>4-1</b>
4.1 Level C and B Activities .....	4-1
4.2 Level D and D+ Activities .....	4-1
4.2.1 Populated Areas .....	4-1
4.2.2 Unpopulated/Secluded Areas .....	4-2
4.3 Visitors .....	4-2
4.4 Site Communications.....	4-2
4.5 Safe Work Practices.....	4-2
4.5.1 Buddy System.....	4-2
4.5.2 Sample Collection and Shipment.....	4-2

## TABLE OF CONTENTS

### (Continued)

	<u>Page</u>
4.5.3 Safety and Hygiene .....	4-3
4.5.4 Confined Space Entry .....	4-3
4.5.5 Adverse Weather Conditions .....	4-3
4.6 Snakebite Injury .....	4-3
4.7 Spider Bite Injury .....	4-4
<b>5.0 PERSONAL PROTECTIVE EQUIPMENT .....</b>	<b>5-1</b>
5.1 PPE Selection .....	5-1
5.1.1 Level D Protection .....	5-1
5.1.2 Modified Level D Protection .....	5-1
5.1.3 Level C Protection .....	5-2
5.2 Respiratory Protection Program .....	5-2
<b>6.0 DECONTAMINATION .....</b>	<b>6-1</b>
6.1 Personnel Decontamination .....	6-1
6.1.1 Washing Facilities .....	6-1
6.2 Effectiveness of Personnel Decontamination .....	6-1
6.3 Equipment Decontamination .....	6-2
<b>7.0 AIR MONITORING AND TESTING .....</b>	<b>7-1</b>
7.1 Personal Monitoring .....	7-1
7.1.1 Integrated Air Monitoring .....	7-2
7.2 Point Source Monitoring .....	7-2
7.3 Perimeter Monitoring .....	7-2
7.4 Equipment Maintenance and Calibration .....	7-3
7.5 Monitoring Documentation .....	7-3
7.6 Instrumentation .....	7-3
7.6.1 Photoionization Detector (PID) .....	7-3
7.6.2 Portable Total Dust Monitor .....	7-3
7.6.3 Integrated Air Monitoring Program .....	7-4
<b>8.0 EMERGENCY PROCEDURES .....</b>	<b>8-1</b>
8.1 Scope .....	8-1
8.2 Pre-Emergency Planning .....	8-1
8.3 Emergency Coordinator .....	8-1
8.4 Communications .....	8-2
8.5 Assembly Area .....	8-2
8.6 Emergency Hospital Route .....	8-2
8.7 Emergency Medical Treatment .....	8-3
8.7.1 Emergency Services .....	8-3
8.7.2 Physical Injury .....	8-3
8.7.3 Chemical Injury .....	8-4
8.7.4 Snakebite Injury .....	8-4
8.8 Emergency Decontamination Procedures .....	8-5

## TABLE OF CONTENTS (Continued)

	<u>Page</u>
8.9 First Aid Equipment.....	8-5
8.10 Notification .....	8-5
8.11 Hazard Assessment .....	8-6
8.12 Security .....	8-6
8.13 Emergency Alerting .....	8-6
8.14 Training .....	8-8
8.15 Spill Containment Procedures.....	8-8
 9.0 INSPECTIONS.....	 9-1
 10.0 MEDICAL MONITORING.....	 10-1
 11.0 ACKNOWLEDGMENT FORM.....	 11-1

## LIST OF FIGURES

8-1 Emergency Hospital Route

## LIST OF ATTACHMENTS

Attachment A	Material Safety Data Sheets
Attachment B	NIOSH Methods for PCBs

## LIST OF ACRONYMS AND ABBREVIATIONS

ANSI	American National Standards Institute
Baker	Baker Environmental, Inc.
BZ	breathing zone
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CPG	Certified Professional Geologist
CPR	cardiopulmonary resuscitation
EO	equipment operator
EZ	exclusion zone
GFCI	ground fault circuit interceptor
HASP	Health and Safety Plan
IARC	International Agency for Research on Cancer
kV	kilovolt
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCB	Marine Corps Base
mg/m <sup>3</sup>	milligram per cubic meter
MSDS	Material Safety Data Sheets
NC	North Carolina
NIOSH	National Institute of Occupational Safety and Health
NTR	Navy Technical Representative
OSHA	Occupational Safety and Health Administration
PCB	polychlorinated biphenyl
PHSO	Project Health and Safety Officer
PID	Photoionization Detector
PPE	Personal Protection Equipment
ppm	parts per million
RCRA	Resource Conservation and Recovery Act
SHSO	Site Health and Safety Officer
SOP	Standard Operating Procedures
SZ	support zone
TWA	Time Weighted Average
USEPA	United States Environmental Protection Agency
UST	underground storage tank

## **1.0 INTRODUCTION**

This site-specific Health and Safety Plan (HASP) is based on an outline developed by the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the United States Coast Guard (USCG), and the United States Environmental Protection Agency's (USEPA) recommended health and safety procedures (Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities). This HASP will, at a minimum, meet the requirements under OSHA Standard 29 Code of Federal Regulations (CFR) 1910.120 and 1926.65 (Hazardous Waste Operations and Emergency Response)

### **1.1 Purpose and Requirements**

The purpose of this HASP is to inform Baker Environmental, Inc. (Baker) personnel, other contractors on the project site, and client representatives, of the currently known and suspected physical, chemical, and environmental hazards. It also describes the minimum safety requirements for the investigation activities at Site 84, MCB Camp Lejeune, Jacksonville, North Carolina.

This HASP is designed to establish personnel protection standards and mandatory safety practices and procedures for on-site remedial activities. This plan assigns responsibilities, establishes standard operating procedures, and provides for contingencies that may arise while operations are being conducted at the site.

All site personnel are required to become familiar with, and follow the provisions of this HASP. The Federal, State, and local laws, including those set forth by OSHA, are also applicable. Subcontractors are expected to provide their own HASP and relevant Standard Operating Procedures (SOPs) that pertain to the activities they are contracted to perform on the site. This information will then become part of the site HASP. All personnel must review the HASP and sign an agreement to comply with its provisions prior to commencing any on-site work. The HASP is considered an operational document which is subject to revisions in response to various site-specific conditions which may be encountered. However, it may be modified/updated with the approval of the Project Health and Safety Officer (PHSO) and Project Manager. Proper notification will be given to the Atlantic Division (LANTDIV), Naval Facilities Engineering Command Navy Technical Representative (NTR) when significant changes to the HASP are implemented.

### **1.2 Site 84 Location, Description and History**

The following section provides detailed information concerning a site location, description, topography and drainage characteristics, history, and previous investigations specific to Site 84, the Building 45 Area.

#### **1.2.1 Site Description**

Site 84 is located approximately 200 yards south of Highway 24 on the main side of MCB, Camp Lejeune, and one mile west of the main gate entrance. The study area is bordered by Building 45 (an electrical substation) to the east and south, Northeast Creek to the west, and railroad tracks to the north. The site area is mostly wooded and covered by thick vegetation or grass. There is a small lagoon, possibly manmade, hidden by trees near the center of the site. The lagoon is roughly circular in shape with a diameter of approximately 50 feet. There is an access road that leads into the site from Highway 24. This access road is fenced and locked at the site boundary. The road runs through the site and terminates at Northeast Creek (refer to Figure 2-1 of the Work Plan).

### **1.2.2 Site Topography and Drainage**

The site is relatively flat with some minor surface mounds in the wooded areas. Overland surface water drainage is west in the direction of Northeast Creek.

### **1.2.3 Site History**

This site is in proximity to a former electric substation. Transformers reportedly containing polychlorinated biphenyls (PCBs) were known to be used and possibly stored at the substation. A transformer was discovered in the wooded area, east of the substation. Additional transformers (approximately 20) potentially containing PCB transformer oil were discovered and removed from the lagoon. Maintenance personnel at Building 45 have indicated that additional transformers may still be buried in areas near the lagoon. However, it was reported that public works had performed minor excavations in the area and did not discover any waste materials.

In addition to the PCB history, there are two active underground storage tank (UST) air sparging remediation activities occurring on the site. There is also a third UST located near the northwest corner of the site near the railroad tracks. These three USTs were reported to contain petroleum product.

### **1.2.4 Previous Investigations**

During an underground storage tank (UST) investigation conducted by O'Brien & Gere (1992), two soil samples, from unknown depths, were collected from the area where the transformer was discovered. Low levels of PCBs (unknown concentrations) were reported in one soil sample. Suspected PCB dielectric fluid was sampled from the discovered transformer and PCBs were reported in the sample (unknown concentrations). The contents of the transformers removed from the lagoon were not sampled (O'Brien and Gere, 1992).

Note that groundwater, surface water, and sediment samples were not collected at the site during previous investigations.

During previous Baker investigations (1995 and 1998) at Site 84 PCB was consistently detected in surface samples at concentrations above the screening standard. The highest PCB concentration was acquired from a 6 – 12 inch boring at a range of 200 parts per million (ppm). PCBs were not detected in any of the groundwater samples, surface water samples, or sediment samples collected from Northeast Creek. PCBs were, however, detected in each of the sediment samples collected from the lagoon.

## **1.3 Scope of Work**

This site investigation is designed to determine the extent of the PCBs around the site and investigate a previous leaking underground storage tank (UST) containing petroleum product. The investigation activities involved with this project are scheduled to involve the following work tasks:

- Monitoring well installations
- Monitoring well development
- Groundwater sampling

- Surface soil sampling
- Subsurface soil borings
- Surface water/sediment samples

#### 1.4 References

The following publications have been referenced in the development and implementation of this HASP.

American Conference of Government Industrial Hygienists (ACGIH). 1998. Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 1998.

National Institute for Occupational Safety and Health/Occupational Safety and Health Administration/United States Coast Guard/United States Environmental Protection Agency. 1985. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.

Occupational Safety and Health Administration. Federal Regulations. 29 CFR 1910 and 1926.

U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH. June 1997. NIOSH Pocket Guide to Chemical Hazards.

United States Environmental Protection Agency, Office of Emergency and Remedial Response, Emergency Response Division. June 1992. Standard Operating Safety Guides.



## **2.0 RESPONSIBILITIES**

The following personnel are designated to carry out the stated job functions for both on and off site activities. (Note: One person may carry out more than one job function, and personnel identified are subject to change.). The responsibilities that correspond with each job function are outlined below.

### **PROJECT MANAGER: Mr. Jeffrey P. Tepsic, P.G.**

The project manager is responsible for assuring that all activities are conducted in accordance with the HASP. The Project Manager has the authority to suspend field activities if employees are in danger of injury or exposure to harmful agents. In addition, the Project Manager is responsible for:

- Assisting the PHSO in Site-Specific HASP development for all phases of the project.
- Designating a Site Health and Safety Officer (SHSO) and other site personnel who will assure compliance with the HASP.
- Reviewing and approving the information presented in this HASP.

### **PROJECT HEALTH AND SAFETY OFFICER (PHSO): Mr. Ronald Krivan, CSP**

The PHSO is responsible for general development of the HASP and will be the primary contact for inquiries as to the contents of the HASP. The PHSO will be consulted before changes to the HASP can be approved or implemented. The PHSO is responsible for:

- Coordinating the review, evaluation, and approval of the HASP.
- Developing amendments to the HASP, when applicable.
- Resolving issues that arise in the field with respect to interpretation or implementation of the HASP.

### **SITE MANAGER: Ms. Ellen Hanna**

The Site Manager is responsible for assuring that all day-to-day activities are conducted in accordance with the HASP. The Site Manager has the immediate authority to suspend field activities if employees are subjected to a situation that can be immediately dangerous to life or health. The Site Manager's responsibilities include:

- Assuring that the appropriate health and safety equipment and PPE has arrived on site and that it is properly maintained.
- Coordinating overall site access and security measures, including documenting all personnel arriving/departing the site (by name, company and time).
- Approving all on site activities, and coordinating site safety and health issues with the SHSO.

- Assisting the SHSO in coordinating emergency procedures with the Naval Activity, emergency medical responders, etc., prior to or during site mobilization activities.
- Assuring compliance with site sanitation procedures and site precautions.
- Coordinating activities with Baker and subcontractor personnel.
- Overseeing the decontamination of field sampling equipment.
- Serving as the backup/alternate Emergency Coordinator.

**SITE HEALTH AND SAFETY OFFICER: Ms. Ellen Hanna**

The SHSO is responsible for site implementation of the HASP. The SHSO also has the immediate authority to suspend field activities if the health or safety of site personnel is endangered; to audit the subcontractor training, fit testing, and medical surveillance records to verify compliance; and, maintaining these records at the Baker Command Post. The SHSO is responsible for:

- Coordinating the pre-entry briefing and subsequent briefings.
- Assuring that monitoring equipment is properly calibrated and operated.
- Inform personnel of the Material Safety Data Sheets (MSDSs) in Attachment A.
- Determining that all Baker personnel have received the required training and medical surveillance prior to entry onto the site.
- Managing health and safety equipment, including instruments, respirators, PPE, etc., that is used in field activities.
- Confirming emergency response provisions (as necessary) in cooperation with Naval Activity Requirements, emergency medical care, etc., prior to or during site mobilization activities.
- Monitoring conditions during field activities to assure compliance with the HASP and evaluate the need for work procedure or PPE changes.
- Documenting, as necessary, pertinent information such as, accident investigation and reporting, safety inspections, a record of site conditions, personnel involved in field activities, and any other relevant health and safety issues
- Overseeing the decontamination of personnel and determine safe boundary procedures for activities requiring Level C or higher protection levels.
- Acting as the Emergency Coordinator and assuring the availability of a communication network and deployment of the HASP and emergency equipment to field teams.

**FIELD TEAM MEMBERS:** Ms. Ellen Hanna, Site Manager  
Ms. Heather Governor, Environmental Scientist  
Mr. Dave Schilling, Project Geologist

The Field Team Members are responsible for:

- Attending training sessions to review the HASP, and staying informed of additional safety and health information.
- Being alert to identified and unidentified hazards and reporting unidentified hazards to the SHSO and Site Manager.
- Offering suggestions, ideas, or recommendations that may improve or enhance site safety.
- Complying with the contents of the HASP.
- Conducting site activities in an orderly and appropriate manner.
- Reporting accidents/injuries, however minor, to the SHSO as soon as possible.

Subcontractor personnel are responsible for:

- Complying with the conditions as outlined under Field Team Members.
- Obtaining the appropriate training, fit testing, and medical surveillance requirements under 29 CFR 1910.120 and 1910.134 and providing this documentation to the Site Manager prior to or during site mobilization.
- Complying with the training and medical surveillance requirements as outlined in Sections 9.0 and 10.0, respectively, and providing his/her own PPE that meets or exceeds the level of protection as outlined in this HASP.

**SUBCONTRACTOR COMPANIES:**

Drilling Operations:	<u>(To be Determined per Baker's Basic Ordering Agreements)</u>
Survey Operations:	<u>(To be Determined per Baker's Basic Ordering Agreements)</u>
Analytical Laboratory:	<u>(To be Determined per Baker's Basic Ordering Agreements)</u>

**NAVFACENGCOM REPRESENTATIVE:**

Mr. Kirk Stevens (NTR)	(757) 322-8422
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### 3.0 SITE HAZARDS CHARACTERIZATION

The site hazards characterization reviews each task and provides information regarding the physical, chemical, and environmental hazards associated with the work tasks to be completed as part of this project.

#### 3.1 Hazard Analysis by Task

The initial site health and safety briefing and subsequent meetings will serve to address the hazards particular to each area and the required procedures for work activities. If new hazards are identified, the SHSO will then add them to this HASP in the field, along with the date of the Addendum. Additionally, site personnel will be expected to follow safe work practices as described in this HASP.

Listed below are summaries for the known or assumed hazards associated with each work task. Levels of protection will be selected based on this task-specific hazard identification, information obtained from previous investigations, and previous experience with similar site investigation activities. Refer to Section 3.2 for specific information regarding the physical hazards, Section 3.3 for specific information regarding the chemical hazards, and Section 3.4 for specific information regarding environmental hazards.

##### 3.1.1 Monitoring Well Installation

###### *Chemical*

- Potentially-contaminated soil, etc. in eyes and on skin.
- Dermal Contact with potentially contaminated material.
- Ingestion of hazardous materials from hand to mouth contact.
- Absorption of PCBs through the skin.
- Inhalation of volatile contaminants or volatile fraction of semivolatile contaminants assumed potentially to be present based on the results of the UST investigation.

###### *Physical/Environmental*

- Heavy objects landing on foot/toe or head.
- Elevated noise levels from heavy equipment operation.
- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Overhead hazards to drill rig operations.
- Interaction with native and potentially hostile animal life.
- Contact with underground utility lines.
- Lifting hazards (muscle strain).

### **3.1.2 Monitoring Well Development**

#### *Chemical*

- Potentially-contaminated groundwater, etc., in eyes and on skin.
- Ingestion of hazardous materials from hand to mouth contact.
- Absorption of PCBs through the skin.
- Inhalation of volatile contaminants or volatile fraction of semivolatile contaminants assumed to be potentially present based on the results of the UST investigation.

#### *Physical/Environmental*

- Slips/trips/falls - sloped, uneven terrain.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and potentially hostile animal life.

### **3.1.3 Groundwater Sampling**

#### *Chemical*

- Skin contact with potentially contaminated water.
- Eye contact from splashing water.
- Ingestion of hazardous materials from hand to mouth contact.
- Absorption of PCBs through the skin.
- Inhalation of volatile contaminants or volatile fraction of semivolatile contaminants emitting from the well opening.

#### *Physical/Environmental*

- Skin irritation from contact with insects and vegetation.
- Lifting hazards (muscle strain, etc.).
- Cuts from using knives while cutting rope or tubing.
- Slips/trips/falls - sloped, uneven terrain.
- Interaction with native and potentially hostile animal life.

### **3.1.4 Surface Soil Sampling**

#### *Chemical*

- Skin contact with potentially PCB contaminated soils.
- Ingestion of hazardous materials from hand to mouth contact.
- Absorption of PCBs through the skin.
- Inhalation of volatile contaminants or volatile fraction of semivolatile contaminants assumed to be potentially present based on the results of the UST investigation.

*Physical/Environmental*

- Slips/trips/falls - sloped, uneven terrain; crawling over and under obstacles.
- Skin irritation from contact with insects and vegetation.
- Interaction with native and potentially hostile animal life.
- Muscle strain from boring with hand auger.

**3.1.5 Subsurface Soil Boring-Sampling**

*Chemical*

- Potentially-contaminated soil, etc., in eyes or on skin.
- Skin contact with potentially PCB contaminated soil.
- Ingestion of potentially contaminated soils from hand to mouth contact.
- Inhalation of volatile contaminants or volatile fraction of semivolatile contaminants.

*Physical/Environmental*

- Elevated noise levels from heavy equipment operations.
- Lifting hazards (muscle strain).
- Skin irritation from contact with insects and vegetation.
- Contact with underground utilities.
- Interaction with native and potentially hostile animal life.
- Heavy objects landing on foot/toe or head.
- Strips/trips/falls from sloped, uneven terrain.

**3.1.6 Equipment Decontamination**

*Chemical*

- Decontamination chemicals (i.e., hexane, isopropanol) in eyes and on skin.

*Physical/Environmental*

- Back spray from the high pressure washing equipment.

**3.2 Physical Hazards**

Some of the physical hazards that may be encountered during on-site remedial activities are listed below and discussed in further detail.

- Slip, trip, and fall
- Thermal Stress
- Noise
- Cuts and Crushing Injuries
- Electrical Safe Work
- Flammable or Combustible Materials
- Underground and Overhead Utility Hazards
- Heavy Equipment

The SHSO, or alternate (SHSO/alternate), will address specific safety procedures to minimize the potential for injury associated with these hazards as part of the weekly site safety meetings.

### **3.2.1 Slip, Trip and Fall**

To avoid trips, slips and falls etc., personnel are to thoroughly inspect the site for hazardous conditions that may result in an injury if unnoticed during work activities. Site personnel will communicate the presence of any identified hazards. If necessary, physical hazards will be barricaded to avoid inadvertent entry into the hazard area.

The following mitigating measures will be used to minimize the slip, trip, and fall hazards:

- Operator awareness
- Delineate area with highest potential
- Good housekeeping
- Work in teams (buddy system)
- Extra caution near the steep bank of the creek

### **3.2.2 Walking and Working Surfaces**

Safe walking/working surfaces are to be maintained in safe condition. Items within this procedure that will be addressed during the investigation activities include:

- All unsafe walking/working surface conditions are promptly corrected or barricaded immediately.
- An effective housekeeping program will be utilized to minimize and eliminate fall hazards.
- Inspections of walking/working surfaces should be conducted periodically.
- Excavations that are five feet or more will be protected in accordance with OSHA excavation requirements.

### **3.2.3 Thermal Stress**

Provisions for monitoring of cold stress and heat stress are outlined in the Baker Health and Safety Programs and Procedures Manual.

### **3.2.4 Noise**

Potential elevated noise levels are anticipated during various phases of the site investigation activities, such as during drilling and subsurface soil boring, therefore, hearing protection will be available for use. The SHSO is responsible for making this determination based upon past experience with the type of equipment in use, and the proximity of personnel to the equipment.

### **3.2.5 Electrical Safe Works**

All portable electrical powered tools will be double insulated or grounded. Ground fault circuit interrupters (GFCIs) will be used where any temporary wiring is in use, such as while using a generator. All electrical power tools, leads, site-lighting and power supply on site should comply with the relevant regulations, standards, and codes of practice.

### **3.2.6 Flammable or Combustible Materials**

In general, the following explosion and/or fire hazards are possible:

- Explosion and fire resulting from ignition of trapped flammable vapors
- Explosion and fire resulting from vehicular accidents or fuels
- Ignition of flammables or combustibles during oxygen/acetylene cutting operations with compressed gasses
- Heavy equipment malfunction

### **3.2.7 Underground and Overhead Utility Hazards**

Underground utility clearance will be obtained for the area during mobilization. It is anticipated that this clearance will be needed to conduct the subsurface soil intrusive activities. If underground utilities are identified, the ground above the utility lines will be physically marked with spray paint or flags. Appropriate utility locators will be notified at least one week prior to intrusive activities, to review the designated areas and to provide utility clearance. A minimum of a 24-inch tolerance zone will be used for underground utilities. Confirmation Geophysics may be performed if an obstruction or utility line is close to an intrusive sampling location.

The generally accepted uniform color code for underground utilities is:

Red - Electric power lines, cables, conduit and lighting cables  
Yellow - Gas, oil, steam, petroleum, or gaseous materials  
Orange - Communication, alarm or signal lines, cables or conduits  
Blue - Water, irrigation, and slurry lines  
Green - Sewers and drain lines  
White - Proposed excavation

The location of all overhead power sources should also be determined, as they can prove especially hazardous during any machine operation. Energized overhead electric lines may present a risk of electrocution. OSHA standards require that equipment maintain certain distances from power lines. For lines 0 to 50 kilovolts (kV), the minimum distance is 10 feet. Lines carrying over 50 kV require that equipment maintain a distance of 10 feet plus an additional 0.4-inch for each 1 kV over 50. On very humid days or during episodes of rain, these distances will be doubled.



### **3.2.8 Heavy Equipment**

One of the primary physical hazards on the site is associated with the use of heavy equipment, which includes the use of a drill rig. Only operators trained, qualified, and authorized will be permitted to operate the heavy equipment.

General hazards associated with the drill rig include moving parts, such as, the auger and cathead. Personnel must remain clear of moving parts and must avoid loose fitting clothing that can become entangled in the moving parts. Personnel working near a drill rig must be aware of the location and operation of the emergency shut off devices. Personnel are to stand clear of the drill rig immediately prior to starting the engine.

Noise from the operation of the heavy equipment will limit verbal warning abilities. Hand signals will be prearranged between operators and personnel working in and around heavy equipment. Backup alarms must operate properly on the heavy equipment.

The drilling subcontractor representatives are to provide any other cautions that need to be observed when working around this equipment during the HASP pre-entry briefing.

Hazards generally associated with drilling equipment operations include the following:

- Motor vehicle exhaust products (e.g., carbon monoxide) from the engine
- Overhead utility wires, (i.e., electrical and telephone), can be hazardous if the boom of the heavy equipment is in an upright position
- Underground pipelines and utility lines can be ruptured or damaged during intrusive operations
- High pressure hydraulic lines and air lines used on equipment are hazardous when they are leaking, worn or incorrectly assembled

#### **Hazard Prevention**

- Review the contaminants suspected to be on site and perform air monitoring as required.
- Shut down and/or divert exhaust fumes.
- All critical moving parts should be inspected daily for weak spots, etc.
- Ear muffs and/or earplugs effectively reduce noise levels.
- Personal protection including safety boots, eye protection, and hard hats will be worn at all times when working around heavy equipment.
- Overhead utilities should be considered "live" until determined to be otherwise.
- A thorough underground utilities search and clearance should be conducted before the commencement of intrusive activities.

- All high-pressure lines should be checked prior to and during use.
- Hand signals will be prearranged between the operator and personnel working around the heavy equipment.
- Personnel are to remain in the field of vision of the operator and remain clear of moving parts.

### 3.3 Chemical Hazards

MSDSs applicable to chemical substances present in wastes found at Site 84 are provided in Attachment A, "Material Safety Data Sheets." Site specific chemical hazards include PCBs and diesel fuel.

The primary chemical hazards are summarized on the following table:

CHEMICAL	EXPOSURE ROUTES	PEL/TLV	HEALTH HAZARDS/ PHYSICAL HAZARDS
Polychlorinated Biphenyls	Skin, eye, inhalation, ingestion	0.5 mg/m <sup>3</sup>	<ul style="list-style-type: none"> <li>• Irritation of eyes, skin; acne-form dermatitis; potential carcinogen;</li> <li>• Reacts with strong oxidizers</li> </ul>
Diesel Fuel	Skin, eye, inhalation, ingestion	400 ppm	<ul style="list-style-type: none"> <li>• A mild skin, eye, mucous membrane irritant; poisonous by ingestion</li> <li>• Volatile, flammable, liquid that can release vapors forming flammable mixtures in air that are explosive when exposed to an ignition source.</li> </ul>

#### 3.3.1 PCBs

The U.S. Department of Health and Human Services has determined that PCBs may reasonably be anticipated to be carcinogens. Human studies to date show that irritations, such as acnelike lesions and rashes, can occur in PCB-exposed workers. Other studies of people with occupational exposure suggest that PCBs might cause liver cancer. Reproductive and developmental effects may also be related to occupational exposure and eating of contaminated fish. While the role of PCBs in producing cancer, reproductive, and developmental effects in humans cannot be clearly delineated, the suggestive evidence provides an additional basis for public health concern about humans who may be exposed to PCBs. The complexity of relating the specific mixtures for which data are available to exposures in the general population has resulted in a tendency to regard all PCBs as having a similar health hazard potential, although this assumption may not be true.

#### 3.3.2 Diesel Fuel

Breathing some fuel oils for short periods may cause nausea, eye irritation, increased blood pressure, headache, light-headedness, loss of appetite, poor coordination, and difficulty concentrating. Breathing diesel fuel vapors for long periods may cause kidney damage and lower your blood's ability to clot.

Drinking small amounts of kerosene may cause vomiting, diarrhea, coughing, stomach swelling and cramps, drowsiness, restlessness, painful breathing, irritability, and unconsciousness. Drinking large amounts of kerosene may cause convulsions, coma, or death. Skin contact with kerosene for short periods may cause itchy, red, sore, or peeling skin.

The International Agency for Research on Cancer (IARC) has determined that some fuel oils (heavy) may possibly cause cancer in humans, but for other fuel oils (light), there is not enough information to make a determination. IARC has also determined that occupational exposures to fuel oils during petroleum refining are probably carcinogenic in humans.

Some studies with mice have suggested that repeated contact with fuel oils may cause liver or skin cancer. However, other mouse studies have found this not to be the case. No studies are available in other animals or in people on the carcinogenic effects of fuel oils.

### **3.4 Environmental Hazards**

The following paragraphs identify the hazards associated with typical flora and fauna issues within North Carolina. If additional concerns are identified, the HASP should be updated accordingly.

#### **3.4.1 Hazardous Flora**

An incidence of contact by individuals to poisonous/thorny plants is high while working in wooded areas. Bare skin should be covered (i.e., long pants and shirt, steel toe boots, leather or cotton gloves, safety glasses, and head protection) as much as practical when working in forested or densely vegetated areas. Personnel should avoid entering an area in the direct path of known poisonous flora (i.e., poison ivy, poison oak, or poison sumac); a secondary route should be selected. Care should also be taken when walking in such areas as uneven terrain or vines may present a tripping hazard.

#### **3.4.2 Hazardous Fauna**

Mosquitoes and gnats pose a nuisance and physical hazard to field personnel; they distract workers, leading to accidents, and pose a physical threat by transmitting live microorganisms. Avoiding the use of perfumes and scented deodorants and donning light colored clothing is preferable. The use of an insect repellent is encouraged and will be provided, as needed.

Poisonous snakes such as the rattlesnake, copperhead, and cottonmouth (water moccasin), all known as pit vipers, are common to the eastern United States. Snakes typically do not attack people but will bite when provoked, angered, or accidentally injured (as when stepped on). When encountering a snake, avoid quick/jerky motions, loud noises, and retreat slowly; do not provoke the snake. If bitten, follow emergency procedures outlined in the Section 4.6.1.

There are two spiders commonly found in the United States whose bite can be serious: the black widow and the brown recluse spider. These bites may be serious, even life threatening. Many other spiders will bite, but they usually do not produce serious complications. The black widow spider measures approximately 1 inch long with its legs extended. It is glossy black in color and has a distinctive yellow-orange marking in the shape of an hourglass on its belly. On its back, however, there is no marking, and unless you happen to turn the spider over, you cannot see this mark. The danger of the black widow spider bite lies in its systemic manifestations. The venom from this spider attacks the nervous system, resulting in severe muscle cramps with boardlike rigidity of the abdominal muscles, tightness in the chest, and difficulty in breathing. Sweating, nausea, and vomiting will also occur.

The brown recluse spider is a little bit smaller than the black widow spider and is dull brown in color. It has a violin-shaped mark on its back, which can be seen when you are looking at the spider from above. The spider gets its name because it tends to live in dark areas, corners, and old unused buildings. The bite from this spider typically produces local effects rather than systemic manifestations. The venom of the brown recluse spider causes severe local tissue damage and can lead to an ulcer and gangrene. The bitten area becomes red, swollen, and tender within a few hours after the bite. A small blister forms, and several days later, this may form a large scab, covering a deep ulcer. Death is rarely reported. If a spider bite by a black widow or brown recluse is suspected, follow emergency procedures in Section 4.6.2.

There is also a potential to contact other dangerous insects; these include fire ants, chiggers, bees, wasps, hornets, mites, fleas, and ticks. Personnel should perform checks periodically and at the end of the work shift, especially when working in grassy or forested areas. Insect bites must be reported to the SHSO.

Before initiating site activities, each individual will be questioned as to any known sensitivities to the previously mentioned organisms or agents.

## **4.0 SITE CONTROL**

To reduce the accidental spread of hazardous substances by workers from a potentially contaminated area to a clean area, zones will be delineated to ensure that work activities and contamination are confined to the appropriate areas, and to keep unauthorized personnel from entering the EZ. The sections below identify the requirements, based on the level of protection in use.

### **4.1 Level C and B Activities**

It is not anticipated that field activities will be conducted at these levels of protection, however, if necessary, all zones for activities conducted under Level C or higher protection levels shall be established utilizing control boundaries between the Exclusion Zone, the CRZ, and the Support Zone (i.e., Clean Zone). These boundaries shall be defined as follows:

- Exclusion Zone - The area where the primary site investigation activity occurs and potential contamination exists.
- Hotline - The boundary between the EZ and CRZ.
- CRZ - The area between the EZ and the Support Zone.
- Contamination Control Line - The boundary between the CRZ and the Support Zone.
- Support Zone - Is an uncontaminated area at the outermost region of the site next to the CRZ and upwind of the investigation activities.

These boundaries will be marked using one or more of the following materials:

- Colored boundary tape, cones, or equivalent for the Hotline or the Decontamination Corridor of the CRZ.
- Barriers for the Contamination Control Line such as posted signs and/or barricades.

### **4.2 Level D and D+ Activities**

All zones for activities conducted under Levels D or D+ will be established according to the following guidelines.

#### **4.2.1 Populated Areas**

In populated areas, EZs for activities conducted under Level D or D+ protection levels shall be established in such a manner as to preclude unauthorized personnel from entering the investigative area. A boundary will be established to separate the EZ from the Support Zone using available materials such as, the contractor's field vehicle, natural boundaries (e.g., buildings, structures, fences), or signs/placards, boundary tape, cones, barricades, etc.

#### **4.2.2 Unpopulated/Secluded Areas**

In unpopulated or secluded areas, the aforementioned materials may not be used due to the exclusive nature of the area and the low risk to outside populations. The SHSO and/or Site Manager will be responsible for making this determination, however, areas of remediated soils will be clearly identified with signs/placards, boundary tape, cones, barricades, etc.

All soil remediation activities will be restricted to the EZ, including any other activities that may result in personnel or equipment exposure to the contaminants of concern. Decontamination of PPE and equipment will be restricted to the CRZ. All support activities will be restricted to SZ.

#### **4.3 Visitors**

The Baker Site Manager will be responsible for all site visitors. All site visitors will receive Basic Visitor Training. Site visitors will not leave the designated support area without permission from the Baker Site Manager. Baker personnel will escort site visitors at all times. Any site visitor authorized to enter the SZ, CRZ, or EZ becomes the responsibility of Baker when they enter that zone.

#### **4.4 Site Communications**

Baker's SHSO will conduct site safety meetings at least once a week to discuss and provide training on the health and safety procedures relevant to site operations or changing site conditions. These weekly safety meetings are intended to reinforce previous training received and to ensure awareness of all site hazards. Attendance at these meetings is mandatory for all on-site personnel. Site safety meeting attendees and meeting minutes will be recorded. Baker's SHSO will maintain a file of these records.

The "buddy system," as described in Section 4.5.1, will be used to maintain communication during non-routine operations. In addition, on-site personnel are responsible for reporting to the SHSO all safety and health related information as it arises, including unsafe situations, and suggestions for additional safe work practices.

#### **4.5 Safe Work Practices**

##### **4.5.1 Buddy System**

When on-site personnel are performing non-routine or potentially hazardous duties, they must work in two or more person teams (i.e., use the buddy system), to ensure that a backup person is available if an emergency arises. If required, the use of a two-way radio, suitable for use in hazardous situations, will be acceptable to meet this requirement when such operation is compatible with respiratory protection requirements. Communications (by portable radio, hand signals, telephone, as appropriate) will be maintained between the employee conducting the operation and the second employee, command post, or SHSO until such time as the operation is completed.

##### **4.5.2 Sample Collection and Shipment**

Chemically protective gloves must be worn whenever soil and liquid samples are taken or handled. When taking samples that may involve the possibility of exposure to or release of airborne contaminants, personal protective equipment, as outlined in Section 5.0, must be used. On-site personnel will be trained in the proper techniques for obtaining representative samples.

#### **4.5.3 Safety and Hygiene**

At a minimum, all personnel engaged in any activity cited herein will wash hands and face prior to eating, chewing, or drinking during work breaks in the area designated by the SHSO/alternate.

Smoking is only permitted in designated areas. Chewing, eating, or drinking in the EZs is prohibited except for an area of the support zone specifically designated as a rest area.

#### **4.5.4 Confined Space Entry**

There are no anticipated confined spaces for any of tasks associated with this project. This will be re-evaluated as needed as the project progresses.

#### **4.5.5 Adverse Weather Conditions**

In the event of adverse weather conditions, the SHSO will determine if work can continue without endangering the health and safety of field workers. Some items to be considered before determining if work should continue are:

- Potential for heat stress and heat-related injuries
- Potential for cold stress and cold-related injuries
- Treacherous weather-related working conditions
- Limited visibility
- Potential for electrical storms

#### **4.6 Snakebite Injury**

In the event of a snakebite injury, the following procedures will be followed.

Look for signs and symptoms such as the characteristic appearance of two small holes, usually about a half-inch apart, with surrounding discoloration, swelling, and pain. Systemic signs (such as, may or may not occur) include weakness, sweating, faintness, and signs of shock.

Provide treatment as follows:

1. Calm the victim and keep affected area still.
2. Contact ambulance if you cannot provide victim with transportation to the nearest hospital.
3. Wash the wound.
4. Keep the affected area below the level of the heart if bite is on the arm or leg.
5. Treat for shock.
6. Monitor airway, breathing, and circulation.
7. Obtain physical description of snake, if possible.

8. Provide the emergency medical responder (either the ambulance attendant or the emergency room at the hospital) with all pertinent information such as how long ago the bite occurred, the type of snake (if known), any known allergic conditions (if known), etc.
9. Inform the SHSO as soon as possible.

#### **4.7 Spider Bite Injury**

The emergency treatment for the black widow spider bite is basic life support. Sometimes the individual is not even aware of having been bitten, or where. Apply cold to the site of the bite if it can be identified. There is a specific antivenin for this spider bite that must be administered by a physician. It is particularly important to identify the spider, and bring it in, if you can.

The emergency treatment for the brown recluse spider is similar to that for the black widow spider except that these bites need local surgical treatment. Spider bite victims should be brought to the hospital. Again, if possible, identification of the spider should be carried out.



## 5.0 PERSONAL PROTECTIVE EQUIPMENT

All on-site personnel will be adequately protected against potential health and safety hazards at the jobsite. A sufficient and diverse inventory of all safety equipment necessary to meet anticipated hazards will be available to all employees. On-site personnel and site visitors will be instructed in the proper use of this equipment, including the below listed items, before entry into the EZ is permitted.

### 5.1 PPE Selection

The primary chemical hazard at the site is the potential exposure to PCBs and fuel oils. Based on daily inspections and air monitoring, the SHSO can change in the levels of protection. The Site Manager also has this authority.

Protective ensembles are described below:

Work Activity	Level of Protection				
	B	C	D+	D	Other
Mobilization				X	
Monitoring well installations			X		
Monitoring well development			X		
Groundwater sampling			X		
Surface soil sampling			X		
Subsurface soil borings			X		
Surface water/sediment samples			X		

#### 5.1.1 Level D Protection

At a minimum, all personnel on site will wear the following as noted:

- Hard hat (American National Standards Institute [ANSI] Z89.1) during heavy equipment operations and while inside the building
- Protective work boots with steel toes (ANSI Z41.1)
- Cotton/Leather gloves, as needed
- Rubber boots, as needed for site conditions

#### 5.1.2 Modified Level D Protection

At a minimum, all personnel within the EZ and the CRZ will wear the following as noted:

- Hard hat (American National Standards Institute [ANSI] Z89.1) during heavy equipment operations and while inside the building
- Chemically protective work boots with steel toes (ANSI Z41.1)
- Safety glasses with side shields or goggles

**NOTE:** Safety glasses will be worn unless there is a high potential for chemical splashes at which time goggles or face shields should be used.

- Ear plugs (if noise levels exceed 85 d.b.a., which is not expected to occur)
- Nitrile gloves
- Chemically protective nitrile inner and outer gloves, as needed
- Rubber boots, as needed for site conditions

### **5.1.3 Level C Protection**

**Level C protection (when required) will consist of modified Level D plus:**

- Full-face-air-purifying respirators with organic vapors/HEPA cartridges if air monitoring indicates an upgrade of protection

## **5.2 Respiratory Protection Program**

The following items are elements of the Baker Respiratory Protection Program:

- Medical approval is required for use of respirators.
- Current fit testing documentation.
- Written procedures will be made available to personnel covering the use of respirators.
- Respirators will be inspected before each use and during post-use cleaning.
- Respirators will be cleaned and disinfected after each day's use, at a minimum.
- Respirators will be stored in a convenient, clean, and sanitary location.
- Respirators will be selected in accordance with OSHA and ANSI standards.

## **6.0 DECONTAMINATION**

### **6.1 Personnel Decontamination**

Personnel leaving the designated exclusion zone area will be thoroughly decontaminated. The following protocol will be used for the decontamination stations according to levels of protection assigned to each tasks (Note: An upgrade to Level C protection will be dependant on site conditions and air monitoring results):

#### **Level C**

1. Equipment drop
2. Outer glove removal/disposal\*
3. Respirator removal
4. Inner glove removal/disposal
5. Hand/face wash
6. Respirator cleaning/sanitizing
7. Equipment wipe down

#### **Level D and D+**

1. Equipment drop
2. Glove removal and disposal D+)\*
3. Hand/face wash
4. Equipment wipe down

The following decontamination equipment is required for Level D+ and C protection levels for the site activities:

- Disposable wipes\*
- Contaminated clothing disposal bag
- Respirator cleaning solution
- Hand and face washing area

\*Optional - depends on degree of contamination and type of PPE used. (Nitrite gloves must be disposed of after sampling, cotton/leather gloves may be reused as appropriate).

Disposable protective clothing will be replaced as necessary. Work gloves and boots will be cleaned, changed, or disposed, if necessary, at the end of the workday and at work breaks. Spent materials will be placed in a container at a location to be designated by the SHSO/alternate.

The CRZ established adjacent to the EZ, will include plastic-lined disposal containers, a detergent wash, and potable water rinse. Workers must undergo decontamination by washing and/or disposal of PPE prior to leaving the CRZ. No clothing or other protective equipment will be allowed off site until cleaned and inspected by the SHSO/alternate.

#### **6.1.1 Washing Facilities**

Washing facilities must be provided to employees in accordance with the requirements of 29 CFR 1926.51(f). Water, soap, and clean towels are to be provided for this purpose. Employees must wash their hands and faces prior to eating or drinking and at the end of the work shift.

### **6.2 Effectiveness of Personnel Decontamination**

The effectiveness of site decontamination methods will be evaluated by the SHSO on a periodic basis. This evaluation may include the observation of personnel decontamination, inspection of respirators, and questioning site personnel. Additional measures may also be employed by the SHSO at his discretion.

### **6.3    Equipment Decontamination**

Provisions for the decontamination of equipment will include a wipe down to remove any visible debris.

## 7.0 AIR MONITORING AND TESTING

Air monitoring will be conducted to identify airborne levels of volatiles and/or PCBs during the various tasks. Air monitoring will be conducted in order to characterize personnel exposures and fugitive emissions from the site contaminants. Results of air monitoring will be used to ensure the proper selection of protective clothing and equipment, including respiratory protection, to protect on-site personnel and off-site receptors from exposure to unacceptable levels of site contaminants. Descriptions of air monitoring strategies, procedures and equipment are provided below.

### 7.1 Personal Monitoring

Personal monitoring will be accomplished using real time monitoring instrumentation directed at the breathing zone (BZ) and using sampling pumps and filter cassettes. The BZ is defined as the area bordered by the outside of the shoulders and from the mid-chest to the top of the head, of work party personnel. Breathing zone monitoring will be performed each time a reading is taken at the point source (i.e., after breaking ground for soil sampling, etc.). The guidelines below identify the protection levels required according to the concentrations measured using each piece of equipment. The real-time instruments include a Photo-ionizing Detector (PID) and a mini-ram. In addition, an oxygen/lower explosive meter (O<sub>2</sub>/LEL) will be available and used on a as needed basis.

#### Direct Reading Air Monitoring

During the soil intrusive and sampling tasks direct reading air monitoring will be performed to determine exposure to workers. A PID meter will be used to monitor for volatiles. A mini-RAM will be used to monitor for air borne particulates.

A summary of air monitoring information is provided in the following table.

Monitoring Device	Monitoring Location/ Personnel	Monitoring Frequency	Action Level	Action
PID	Adjacent to the sampling or intrusive location/ Equipment Operator (EO), Field Personnel	Periodic during Monitoring well installations and development and Groundwater, Surface soil, and Subsurface soil sampling	<1 meter units (mu)* 1-5 mu* 5-50 mu*	Level D Level C Stop Work and Consult SHSO
Mini-Ram (total dust)	Adjacent to the sampling or intrusive location/ Equipment Operator (EO), Field Personnel	Periodic during Monitoring well installations and Subsurface soil borings	< 5.0 mg/m <sup>3</sup> (TWA) 5.0 mg/m <sup>3</sup> - ≥ 5.0 mg/m <sup>3</sup>	Level D  Level C

\*Sustained levels above background for 1 minute or longer

### 7.1.1 Integrated Air Monitoring

Integrated air sampling for personnel exposure characterization will be performed during soil intrusive activities. Samples will be collected on various Field Personnel at the discretion of the SHSO. Sampling will be conducted for PCBs using NIOSH Method. A summary of air monitoring information is given in the Table below.

Monitoring Device	Monitoring Location/ Personnel	Monitoring Frequency	Action Level	Action
Air Sampling Pump NIOSH 5503 (PCBs)	Breathing Zone/ (EO), Field Personnel	1 Sample on an individual during the first two days of soil intrusive activities. Further sampling will be based on initial results and discretion of the SHSO	$< 0.5 \text{ mg/m}^3$ $\geq 0.5 \text{ mg/m}^3$	Level D Level C

National Institute of Occupational Safety and Health (NIOSH) Method 5503 (PCBs) monitoring will be conducted to detect concentrations of PCBs in ambient air. Specific flow rates and sampling media will be used to collect these samples as outlined in the respective method. Refer to Attachment B to review the respective NIOSH methods for PCBs.

One field blank will be included with each set of samples sent to the lab for analysis. Each sampling pump will be calibrated with the representative sampler in line before and after the sampling. The sample pump will be set at a known flow rate for up to 8 hours for a total sample size that will represent Time Weighted Average (TWA) measurements.

Samples will be collected on employees involved with potential PCB exposure. The samples will be representative of the full shift or duration of the task.

### 7.2 Point Source Monitoring

Point source monitoring, is defined as monitoring performed at the source of the sampling/investigative activity. Point source monitoring will comply with the action levels outlined below. Instrumentation to be used will include a PID and air sampling cassettes.

#### PID

- If detecting levels greater than background, immediately measure the BZ levels following the action levels set forth in Section 7.1.1.
- Note levels in both the point source area and breathing zone.
- Inform SHSO and Site Manager of readings.

### 7.3 Perimeter Monitoring

A PID and Miniram will be used to monitor the perimeter of the EZ as necessary to determine safe areas during a work stoppage if concentrations meet the work stoppage criteria identified in Section 7.1.1.

#### **7.4     Equipment Maintenance and Calibration**

Procedures for the return of equipment to inventory and for maintenance of the equipment shall be followed in order to assure that the optimum level of operation is maintained for the item. Equipment calibration under the direction of the SHSO will be completed daily before use and calibration information entered onto the equipment calibration form. Procedures for equipment maintenance and calibration will follow those instructions found in the operating manual provided by the manufacturer, which is included with each piece of equipment. These forms will be placed in the project files upon completion of the field activities.

If equipment field checks indicate that any piece of equipment is operating incorrectly and field repair cannot be made, the equipment will be immediately tagged and removed from service. Replacement equipment will meet the same specifications for accuracy and sensitivity as the equipment removed from service.

#### **7.5     Monitoring Documentation**

As environmental monitoring is performed, documentation of the results will be entered into the field logbook of the SHSO or other personnel performing the monitoring. Documentation will include the date, time, instrument result, general location, and specific location, such as point source, breathing zone, or area, and weather conditions during the monitoring time period. Copies of the field logbook will be maintained on-site until the end of the field activities, whereby the logbooks will become part of the permanent file.

#### **7.6     Instrumentation**

The following is a description of the air monitoring equipment to be used at this site.

##### **7.6.1     Photoionization Detector (PID)**

###### **7.6.1.1     Calibration Method/Frequencies**

The PID Model PI 101 or the Mini-RAE 2000 is designed for trace gas analysis in ambient air and will be calibrated with certified standards of isobutylene.

A PID with a 10.2 eV or 10.6 lamp will be used at the site. This lamp has been determined to be most responsive to the contaminants on site. Optional probes containing lamps of 9.5 and 11.7 eV are interchangeable in use within individual read-out assemblies for different applications.

##### **7.6.2     Portable Total Dust Monitor**

Real-Time Aerosol Monitor (Mini Ram Model PDM-3)

###### **7.6.2.1     Principle of Operation:**

Detection of light in the near infrared region back-scattered to a sensor (photovoltaic detector) by airborne particulate in a sensing volume. The higher the dust concentration the more back-scattering of light to the sensor, resulting in increased readings.

#### 7.6.2.2 Calibration Methods/Frequencies:

The device calibrated at the factory against an air sampling filter/gravimetric analysis reference method. There is no field calibration method or procedure for calibrating the mini-ram monitor. However, it is recommended that the mini-ram monitor be re-zeroed once a week. During a zero check, the sampled air passes through the purge air filter and dryer to effect a self-cleaning of the optical chamber.

#### 7.6.2.3 Preventative Maintenance:

Maintenance of the mini-ram consists of replacement of filters and desiccant; battery replacement; and cleaning of the optical detection assembly.

### 7.6.3 **Integrated Air Monitoring Program**

Gilian Air Sampling Pump (or equivalent)

#### 7.6.3.1 Principle of Operation:

Air sampling pump is calibrated to draw a specified airflow rate (liters per minute) for a designated period of time. Volume of air sampled is then calculated as follows:

Flow rate (liter/min.) x sample time (min.) = sample volume (liters)

A bubble meter is used to calibrate the air-sampling pumps. Each pump is equipped with a rotameter that shows the flow rate during the sampling period. The pump is equipped with a rechargeable battery for 8-hour average sampling times; must be recharged for at least 16 hours.

Collection Media: glass fiber filter cassette with a florasil tube for PCBs.

#### 7.6.3.2 Calibration Methods/Frequencies:

Flow rate calibration can be accomplished by using primary standard soap and the Gilibrator Calibrator (or equivalent). The Gilibrator calibrator allows rapid flow rate determination with direct read-out on the built-in display.

Connect the sampler to the calibrator, press the ON push button, and then push the plunger to start a bubble up the flow cell. The flow rate is automatically calculated and shown on the display. Subsequent readings are averaged with the previous readings. It is recommended that calibration of the sampler be checked prior to the start of and after each sampling period.

#### 7.6.3.3 Preventative Maintenance:

The Gilian air-sampling pump should not require special maintenance or adjustments under normal conditions. However, as with all instruments, the sampling pump does require some basic care. Basic maintenance of the pump consists of filter replacement, installing and removing battery packs, storage conditions, and electronic control assembly.



## **8.0 EMERGENCY PROCEDURES**

### **8.1 Scope**

The activities to be conducted under this HASP are not remediation (cleanup), but investigative, therefore the potential for a "release" to air, water or soil is low. However, other emergencies, such as fire or personnel injury may occur. If so, local emergency response groups will be called in to handle the incident, as necessary.

### **8.2 Pre-Emergency Planning**

All applicable Navy/local emergency response contacts (On-Scene Commander, Fire Department, Security, Ambulance, Hospital, etc.) at MCB Camp Lejeune will be contacted prior to or during site mobilization activities. This notification will be performed by the SHSO and/or Site Manager. The information discussed may include:

- A description of site activities.
- Anticipated site hazards.
- Hazardous chemicals to be used on site.
- Expected length of time on site.
- Specific requirements the emergency response facilities may require.
- Confirmation of emergency phone numbers.

Specific points of contact, where applicable, will be established and added to the HASP. If requested, Material Safety Data Sheets will be provided at this time.

### **8.3 Emergency Coordinator**

The SHSO acting as the Emergency Coordinator is responsible for field implementation of these Emergency Procedures. The Emergency Coordinator is responsible for reacting (not responding) to emergencies. As the Emergency Coordinator, specific duties include:

- Familiarizing all on-site personnel with the emergency procedures and the emergency coordinator's authority.
- Identifying the nearest telephone in the event of an emergency.
- Communicating site emergency procedures and requirements to all Baker and subcontractor personnel.
- Specifying the Site Manager as the backup/alternate Emergency Coordinator.
- Controlling activities of subcontractors and contacting the emergency response groups, as necessary.
- Anticipating, identifying, and assessing, fires, explosions, chemical releases, and other emergency situations to the best of their abilities, and providing this information to the off-site emergency groups) responding.
- Familiarity with site personnel trained in emergency first aid and adult CPR.

All on-site personnel, whether involved in emergency response or not, will be notified of their responsibilities by the Emergency Coordinator in an emergency. They will be familiar with the emergency procedures and the Emergency Coordinator's authority.

#### **8.4     Communications**

Internal communications will rely on direct communication (via verbal or two-way radios) between site personnel. External communications will employ a cellular (portable) telephone in the Baker Field Vehicle.

The "Buddy System" will be in effect at all times; any failure of communication requires an evaluation of whether personnel should discontinue activities.

Coordination between Baker and subcontractor personnel is the responsibility of the Site Manager. The best means for securing the lines of communication will be determined prior to start-up by on-site project personnel.

Emergency telephone numbers will be maintained in each Baker Field Vehicle. The list of emergency phone numbers is presented in Table 8-1.

#### **8.5     Assembly Area**

In the event of an emergency personnel will be instructed before the start of operations to meet upwind of the emergency. Where applicable, personnel will exit the work area through the contamination reduction zone. A general evacuation location will be predetermined based on prevailing wind directions during the HASP training. At this location, emergency needs will be provided, such as:

- Assembly for evacuated personnel
- First aid for injured personnel
- Decontamination material
- Communications.

#### **8.6     Emergency Hospital Route**

An emergency hospital route (Figure 8-1) depicting the route to the hospital will be located in the onsite Baker Field Vehicle. Personnel will be informed of the location of the figure and the directions to the hospital. The Naval Hospital will be used for life-threatening injuries or potential chemical exposure (per prior civilian humanitarian agreement). Directions to the Base and Public Hospital from each site are provided below.

##### **Site 84**

The following are directions to the base Naval Hospital (Building NH100) from Site 84 (refer to Figure 8-1):

1. Turn right onto Route 24 (Lejeune Boulevard) and continue following Lejeune Boulevard through the main gate.
2. At traffic light turn right onto Brewster Boulevard.
3. Continue on Brewster Boulevard until intersecting with driveway to Naval Hospital on right (approximately 0.75 miles).
4. Follow signs for emergency room entrance (bear to right).

Directions to Onslow County Memorial Hospital (317 Western Boulevard) from **Site 84** (refer to Figure 8-1).

1. Turn left onto Route 24 (Lejeune Boulevard) until intersecting with Western Boulevard.
2. Turn right onto Western Boulevard.
3. Continue on Western Boulevard to the fifth stop light and the hospital will be on the left hand side.
4. Follow directions to emergency room entrance.

## **8.7 Emergency Medical Treatment**

If injuries are not serious or life threatening, affected personnel may be transported by other site personnel to the local medical facility, if necessary. Emergency medical response personnel will be contacted in the event of serious or multiple injuries. Medical personnel will be provided with all available information regarding the nature of the incident, chemicals involved, etc.

### **8.7.1 Emergency Services**

The nearest public hospital is Onslow County Memorial Hospital located at 317 Western Boulevard, Jacksonville, NC, phone No.: **(919) 577-2240** (on base) and **(919) 577-2240** or **911** (off-base).

Note: For chemical emergencies, personnel must be transported to Building NH100 (Naval Hospital).

Local ambulance service is available from the Naval Ambulance Service at **911** and the City of Jacksonville at **(919) 455-9119**. Contact should be made with emergency personnel prior to the start of activities (See Section 8.1).

There will be a minimum of 2 persons on each site that will be trained in emergency first aid and CPR.

Instances requiring treatment beyond "first-aid" will be handled at appropriate facilities and reported to the Project Manager and PHSO within 24 hours. Subcontractors will be responsible for securing proper medical attention for their employees. Baker may assist the subcontractor if necessary.

### **8.7.2 Physical Injury**

If an employee working in a contaminated area is physically injured, first aid procedures are to be followed. If the employee can be moved, he/she will be taken to the edge of the work area and decontaminated, if necessary (refer to Section 8.7). Depending on the severity of the injury, emergency medical response from Navy personnel may be sought to stabilize victim for transport to public hospitals. Emergency first aid may be administered by Baker personnel prior to transporting to an awaiting ambulance or to a local emergency medical facility, as appropriate.

### 8.7.3 Chemical Injury

If the injury to a worker is chemical in nature (e.g., direct contact/exposure), the following first aid procedures are to be instituted:

- Eye Exposure - If contaminated solid or liquid gets into the eyes, wash the eyes immediately at the 15-minute emergency eyewash station (or with the emergency eye wash bottle when an eye wash station is not available). Obtain medical attention immediately.

**NOTE:** Contact lenses will not be worn while working at the site.

- Skin Exposure - If contaminated solid or liquid gets on the skin, promptly wash the contaminated skin using soap or mild detergent and water. If solids or liquids penetrate through the clothing, remove the clothing immediately and wash the skin using soap or mild detergent and water. Obtain medical attention immediately.
- Swallowing - If contaminated solid or liquid has been swallowed immediately contact the Poison Control Center at the Duke University Medical Center, Durham, North Carolina at 1-800-672-1697. Do not induce vomiting in an unconscious person. Obtain medical attention as directed by the Poison Control Center.
- Breathing - If a person has difficulty breathing, move the exposed person to fresh air at once. If breathing is not evident, check for pulse and perform appropriate first aid (either rescue breathing or CPR) depending on the condition. Obtain medical attention immediately.

### 8.7.4 Snakebite Injury

In the event of a snakebite injury, the following procedures will be followed.

Look for signs and symptoms such as the characteristic appearance of two small holes, usually about a half inch apart, with surrounding discoloration, swelling, and pain. Systematic signs (which may or may not occur) including weakness, sweating, faintness, and signs of shock.

Provide treatment as follows:

1. Calm the victim and keep affected area still.
2. Contact ambulance if you cannot provide the victim with transportation to the nearest medical facility.
3. Wash the wound.
4. Keep the affected area below the level of the heart if bite is on the arm or leg.
5. Treat for shock.
6. Monitor airway, breathing, and circulation.

7. Obtain physical description of snake, if possible.
8. Provide the emergency medical responder (either the ambulance attendant or the emergency room at the hospital) with all pertinent information such as: how long ago the bite occurred, the type of snake (if known), any known allergic conditions (if known), etc.
9. Inform the SHSO immediately if a snakebite injury has occurred.

### 8.8 Emergency Decontamination Procedures

In the event of a medical emergency, patients are to be adequately decontaminated before transfer (if possible) to prevent contamination of the medical transport vehicle and medical facility. Emergency personnel decontamination will include the following, depending on the level of protection.\*

Level D	Level D+	Level C
<ul style="list-style-type: none"> <li>• Equipment drop</li> <li>• Tape, boot, and glove removal</li> <li>• Coverall removal</li> </ul>	<ul style="list-style-type: none"> <li>• Equipment drop</li> <li>• Tape, outer boot, and glove removal</li> <li>• Coverall removal/ disposal</li> <li>• Inner glove removal/ disposal</li> </ul>	<ul style="list-style-type: none"> <li>• Equipment drop</li> <li>• Tape, outer boot, and glove removal</li> <li>• Coverall removal/ disposal</li> <li>• Respirator removal</li> <li>• Inner glove removal/ disposal</li> </ul>

If necessary, one of the site personnel equipped with appropriate PPE may accompany the injured worker and perform decontamination with supervision of medical personnel.

### 8.9 First Aid Equipment

Emergency and first aid equipment can be found at the following locations:

Fire Extinguisher:	<u>Contractor Field Vehicle</u>
First aid kit:	<u>Baker Field Vehicle</u>
Emergency eye wash bottle:	<u>Baker Field Vehicle</u>

### 8.10 Notification

If the Emergency Coordinator determines that the site has an uncontrolled situation, such as a spill, fire, or explosion, that could threaten human health or the environment, they will report their findings to the Base Fire Department, the Activity Contact, the Project Manager, and the NTR as soon as possible. The notification report will include:

- Description of incident (e.g., release, fire).
- Name and telephone number of individual reporting the emergency.
- Location of incident.
- Name and quantity of material (s) involved (if known).
- The extent of injuries, and number of casualties.
- The possible hazards to human health or the environment.

- Assistance that is requested.

### **8.11 Hazard Assessment**

For the purposes of providing information to the Navy On-Scene Commander, the Emergency Coordinator will assess possible hazards to human health or the environment that may result from an uncontrolled situation, to the best of their abilities, incorporating the following steps, as appropriate.

- Assess the immediate need to protect human health and safety.
- Identify, where possible, the materials involved in the incident including exposure and/or release pathways and the quantities of materials involved.
- Inform appropriate personnel as identified in Section 8.10, who will determine if release of material(s) meets EPA requirements for reportable quantities for spills under the RCRA or CERCLA.

This assessment may consider both the direct and indirect effects of the chemical release, fire, explosion, or severe weather conditions (e.g., the effects of any toxic, irritating, or asphyxiating gases that are liberated).

### **8.12 Security**

During activation of these Emergency Procedures, the Emergency Coordinator or his/her designated representative will control access to the site and maintain an incident log until the appropriate personnel, such as the Navy On-Scene Commander arrives and takes control. The incident log may include:

- Activities that have occurred since the incident was first reported.
- Rescue, response, and PPE used to evacuate personnel.

### **8.13 Emergency Alerting**

**Personnel Injury in the Work Zone:**

- Initiate a verbal warning or one long airhorn blast and move all unaffected site personnel to the support zone (for Level D/D+) or the CRZ (for Level C or higher).
- Send the rescue team into the Work Zone (if required) to remove the injured person to the hotline.
- Have the SHSO and/or Site Manager evaluate the nature of the injury, and assure that the affected person is decontaminated according to Section 8.8.
- If required, contact an ambulance and/or the designated medical facility.

No persons shall reenter the Work Zone until an accident investigation is performed by the SHSO and/or the Site Manager.

**Personnel Injury in the Support Zone:**

- The Site Manager and SHSO will assess the nature of the injury; if the cause of the injury or loss of the injured person does not affect the performance of other site personnel, operations may continue.
- If the injury increases the risk to others, a verbal warning or one long airhorn blast shall be sounded and all remaining site personnel will move to the command post for further instructions.
- Activities on site will stop until the added risk is mitigated.

**Fire/Explosion:**

- Initiate a warning and move all site personnel to the support zone (for Level D/D+) or the CRZ (for Level C or higher).
- Alert the fire and security departments and move all nonessential personnel to the Baker Command Post to await further instructions.
- Activities will stop until the added risk is mitigated.

**Personal Protective Equipment Failure:**

- If any site worker experiences difficulty, failure or alteration of protective equipment that affects the protection factor, that person and his/her buddy shall immediately cease work activities, leave the Work Zone, and repair or replace the defective equipment.
- Reentry will not be permitted until the equipment has been repaired or replaced.

**Other Equipment Failure:**

- Rescue, response, and PPE used to evacuate personnel.
- If any other equipment on site fails to operate properly, the Field Team Leader shall notify the Site Manager and SHSO to determine the effect of this failure on site operations.
- If the failure affects the safety of site personnel, work with the equipment will cease until the situation is evaluated and appropriate actions taken.

In all situations, when an on-site emergency results in evacuation of the Work Zone, personnel shall not reenter until:

1. The conditions resulting in the emergency have been corrected.
2. The hazards have been reassessed.
3. The HASP has been reviewed and, if appropriate, modified.
4. Site personnel have been briefed on any changes in the HASP.

#### **8.14 Training**

Site personnel will read the details in the Emergency Procedures prior to the initial HASP training. The Emergency Procedures will be reviewed by site personnel during the pre-entry briefing.

#### **8.15 Spill Containment Procedures**

In the event that a small, easily-controlled spill of hazardous substances (gasoline, oil, etc.) occurs during the implementation of field activities, spill containment will be utilized to prevent the additional migration of contaminants through the site area. Large, uncontrolled spills will be handled by qualified response organizations under the direction of the Base personnel and/or the Navy On-Scene Commander. Any release to soils or surface waters equaling or exceeding the reportable quantities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the USEPA Clean Water Act will immediately be reported to the Base Environmental Management Department.



## 9.0 INSPECTIONS

The SHSO, or designated qualified representatives, will make regular and continuing inspections of all facilities and operations within the scope of the contract.

Baker personnel will make periodic site safety and health inspections. These inspections will include, but are not limited to, the following:

- General Order and Housekeeping: On a daily basis keep walkways and traffic areas clear. Inspect general site conditions on a daily basis.
- Tools: Check for burrs, dull points, heads properly fitted on handles and if power driven, that they are in good working order prior to use.
- Flammable and Combustible Materials: Inspect the site for proper placement or storage of flammable and combustible materials on a weekly basis. Burning, welding, or other fire-generating work will be performed only after inspections are made to ensure that no fire hazard is present. Approval will be obtained by the SHSO, the Site Manager, and the appropriate client site representative.
- Fire Protection Devices: Portable fire extinguishers will be inspected with the inspection tag initialed monthly. Weekly visual inspections of the fire extinguishers will also be conducted.
- Noise: Noise control at the source is required, if feasible. Properly fitted ear protection will be worn when noise levels cannot be controlled.
- General Conditions: Assure that personal protective equipment and clothing used is as required on a daily basis. Check for proper lighting at all points. Inspect security fence and barriers to ensure proper function on at least a weekly basis. Continually check that physical hazards are controlled or removed.
- First-aid kits: The contents of the first-aid kits will be checked by the SHSO at least weekly to ensure that the expended items are replaced.
- Extension cords: Worn or frayed electrical cords must not be used. Extension cords must not be fastened with staples, hung from nails, or suspended by wire. Extension cords are to be inspected prior to each use.

## **10.0 MEDICAL MONITORING**

The medical monitoring requirements will conform to the established Baker employee medical surveillance policy. Personnel who are engaged in hazardous waste operations, or who are or may be exposed to hazardous substances or health hazards, or who wear respirators for 30 days or more a year are required to take baseline, periodic and exit physical examinations. Personnel who are temporarily assigned to fieldwork for a period of four or more weeks are required to take a pre-assignment examination.

Medical examinations or consultations are available to all employees who may have been exposed to hazardous substances at concentrations above the permissible exposure limits. Regular medical surveillance examinations are to ensure that individuals working in the field are physically fit to cope with the increased stress of working in the required personal protective equipment. They also provide initial and ongoing medical data to help detect chemical exposure to toxic substances or to harmful physical agents. The Baker SHSO will enforce the medical monitoring program requirements and carry out additional measures as necessary.

All site personnel are responsible for reading this Health and Safety Plan and being familiar with their responsibilities and requirements. After completing this review, personnel must sign below to acknowledge that they have read and understood the Health and Safety Plan.

Date[illegible]

Name

Signature

Date


---

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## FIGURES

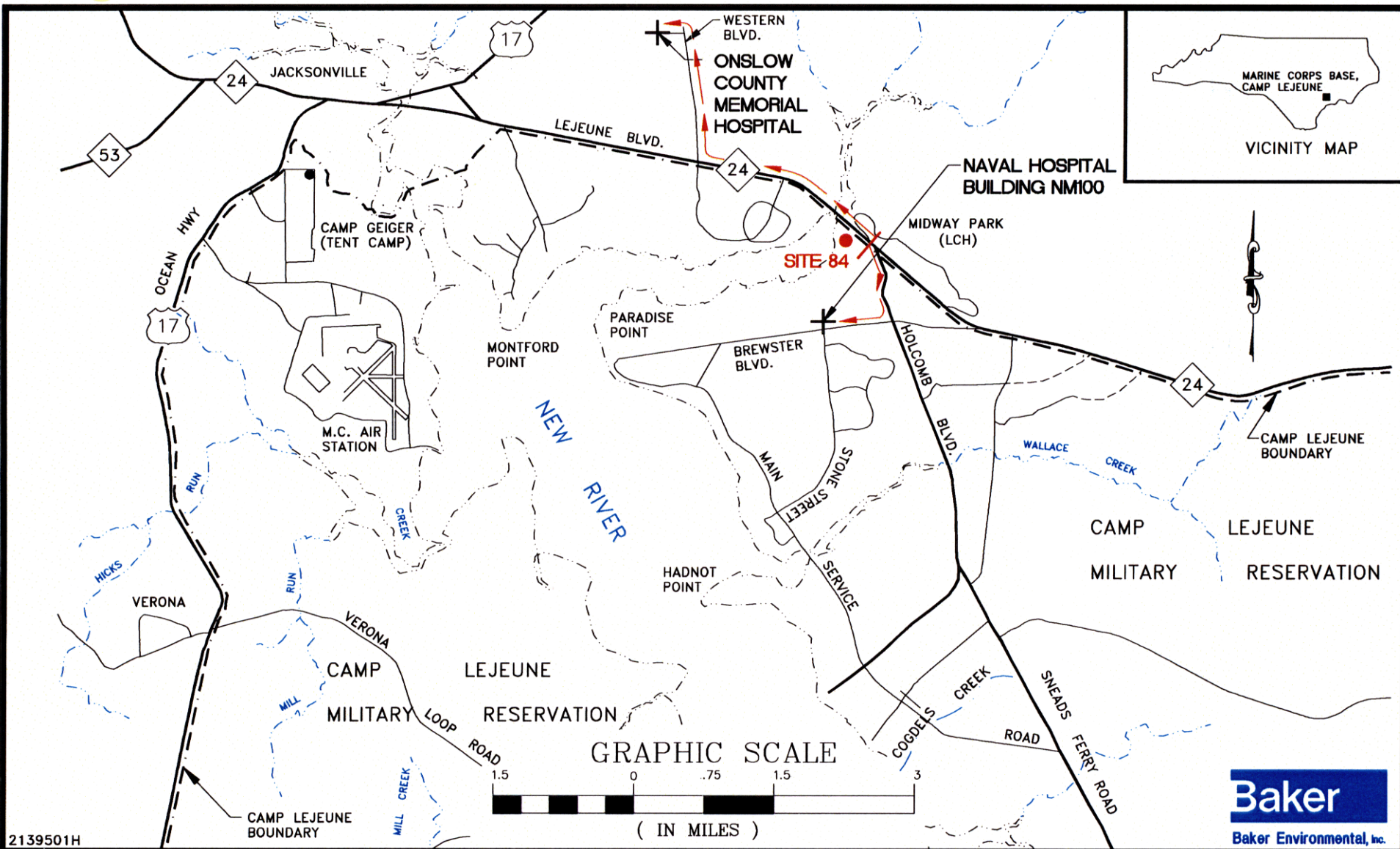


FIGURE 8-1  
EMERGENCY HOSPITAL ROUTE  
SITE 84/BUILDING 45 AREA  
CTO - 0139 (CLEAN II)

MARINE CORPS BASE, CAMP LEJEUNE  
NORTH CAROLINA



## **ATTACHMENTS**

**ATTACHMENT A**  
**MATERIAL SAFETY DATA SHEETS**

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# Genium Publishing Corporation

1145 Catalyn Street  
Schenectady, NY 12303-1836 USA  
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## Material Safety Data Sheets Collection:

Sheet No. 470  
Diesel Fuel Oil No. 2-D

Issued: 10/81

Revision: A, 11/90

### Section 1. Material Identification

33

**Diesel Fuel Oil No. 2-D Description:** Diesel fuel is obtained from the middle distillate in petroleum separation; a distillate oil of low sulfur content. It is composed chiefly of unbranched paraffins. Diesel fuel is available in various grades, one of which is synonymous with fuel oil No. 2-D. This diesel fuel oil requires a minimum Cetane No. (efficiency rating for diesel fuel comparable to octane number ratings for gasoline) of 40 (ASTM D613). Used as a fuel for trucks, ships, and other automotive engines; as mosquito control (coating on breeding waters); and for drilling muds.

**Other Designations:** CAS No. 68334-30-5, diesel fuel.

**Manufacturer:** Contact your supplier or distributor. Consult the latest *Chemicalweek Buyers' Guide*<sup>(73)</sup> for a suppliers list.

**Cautions:** Diesel fuel oil No. 2-D is a skin irritant and central nervous depressant with high mist concentrations. It is an environmental hazard and moderate fire risk.

NFPA  
2  
0 0  
-  
HMIS  
H 0  
F 2  
R 0  
PPG\*  
\* Sec. 8

### Section 2. Ingredients and Occupational Exposure Limits

Diesel fuel oil No. 2-D\*

1989 OSHA PEL

None established

1990-91 ACGIH TLV

Mineral Oil Mist

TWA: 5 mg/m<sup>3</sup>†

STEL: 10 mg/m<sup>3</sup>

1988 NIOSH REL

None established

1985-86 Toxicity Data‡

Rat, oral, LD<sub>50</sub>: 9 g/kg produces gastrointestinal (hypermotility, diarrhea) effects

\* Diesel fuel No. 2-D tends to be low in aromatics and high in paraffinics. This fuel oil is complex mixture of: 1) >95% paraffinic, olefinic, naphthenic, and aromatic hydrocarbons, 2) sulfur (<0.5%), and 3) benzene (<100 ppm). [A low benzene level reduces carcinogenic risk. Fuel oils can be exempted under the benzene standard (29 CFR 1910.1028)]. Although low in the fuel itself, benzene concentrations are likely to be much higher in processing areas.

† As sampled by nonvapor-collecting method.

‡ Monitor NIOSH, RTECS (HZ1800000), for future toxicity data.

### Section 3. Physical Data

Boiling Point Range: 340 to 675 F (171 to 358 C)

Viscosity: 1.9 to 4.1 centistoke at 104 F (40 C)

Appearance and Odor: Brown, slightly viscous liquid.

Specific Gravity: <0.86

Water Solubility: Insoluble

### Section 4. Fire and Explosion Data

Flash Point: 125 F (52 C) min.

Autoignition Temperature: >500 F (932 C)

LEL: 0.6% v/v

UEL: 7.5% v/v

**Extinguishing Media:** Use dry chemical, carbon dioxide, or foam to fight fire. Use a water spray to cool fire exposed containers. Do not use a forced water spray directly on burning oil since this will scatter the fire. Use a smothering technique for extinguishing fire.

**Unusual Fire or Explosion Hazards:** Diesel fuel oil No. 2-D is a OSHA Class II combustible liquid. Its volatility is similar to that of gas oil. Vapors may travel to a source of ignition and flash back.

**Special Fire-fighting Procedures:** Isolate hazard area and deny entry. Since fire may produce toxic fumes, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand or positive-pressure mode and full protective clothing. If feasible, remove containers from fire. Be aware of runoff from fire control methods. Do not release to sewers or waterways due to pollution and fire or explosion hazard.

### Section 5. Reactivity Data

**Stability/Polymerization:** Diesel fuel oil No. 2-D is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.

**Chemical Incompatibilities:** It is incompatible with strong oxidizing agents; heating greatly increases the fire hazard.

**Conditions to Avoid:** Avoid heat and ignition sources.

**Hazardous Products of Decomposition:** Thermal oxidative decomposition of diesel fuel oil No. 2-D can produce various hydrocarbons and hydrocarbon derivatives, and other partial oxidation products such as carbon dioxide, carbon monoxide, and sulfur dioxide.

**Section 6. Health Hazard Data**

**Carcinogenicity:** Although the IARC has not assigned an overall evaluation to diesel fuels as a group, it has evaluated occupational exposures in petroleum refining as an IARC probable human carcinogen (Group 2A). It has evaluated distillate (light) diesel oils as not classifiable as human carcinogens (Group 3).

**Summary of Risks:** Although diesel fuel's toxicologic effects should resemble kerosene's, they are somewhat more pronounced due to additives such as sulfurized esters. Excessive inhalation of aerosol or mist can cause respiratory tract irritation, headache, dizziness, nausea, vomiting, and loss of coordination, depending on concentration and exposure time. When removed from exposure area, affected persons usually recover completely. If vomiting occurs after ingestion and if oil is aspirated into the lungs, hemorrhaging and pulmonary edema, progressing to renal involvement and chemical pneumonitis, may result. A comparative ratio of oral to aspirated lethal doses may be 1 pt vs. 5 ml. Aspiration may also result in transient CNS depression or excitement. Secondary effects may include hypoxia (insufficient oxygen in body cells), infection, pneumatocele formation, and chronic lung dysfunction. Inhalation may result in euphoria, cardiac dysrhythmias, respiratory arrest, and CNS toxicity. Prolonged or repeated skin contact may irritate hair follicles and block sebaceous glands, producing a rash of acne pimples and spots, usually on arms and legs.

**Medical Conditions Aggravated by Long-Term Exposure:** None reported.

**Target Organs:** Central nervous system, skin, and mucous membranes.

**Primary Entry Routes:** Inhalation, ingestion.

**Acute Effects:** Systemic effects from ingestion include gastrointestinal irritation, vomiting, diarrhea, and in severe cases central nervous system depression, progressing to coma or death. Inhalation of aerosols or mists may result in increased rate of respiration, tachycardia (excessively rapid heart beat), and cyanosis (dark purplish discoloration of the skin and mucous membranes caused by deficient blood oxygenation).

**Chronic Effects:** Repeated contact with the skin causes dermatitis.

**FIRST AID**

**Eyes:** Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.

**Skin:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. If large areas of the body have been exposed or if irritation persists, get medical help immediately. Wash affected area with soap and water.

**Inhalation:** Remove exposed person to fresh air and support breathing as needed.

**Ingestion:** Never give anything by mouth to an unconscious or convulsing person. If ingested, *do not induce vomiting* due to aspiration hazard.

Contact a physician immediately. Position to avoid aspiration.

After first aid, get appropriate in-plant, paramedic, or community medical support.

**Note to Physicians:** Gastric lavage is contraindicated due to aspiration hazard. Preferred antidotes are charcoal and milk. In cases of severe aspiration pneumonitis, consider monitoring arterial blood gases to ensure adequate ventilation. Observe the patient for 6 hr. If vital signs become abnormal or symptoms develop, obtain a chest x-ray.

**Section 7. Spill, Leak, and Disposal Procedures**

**Spill/Leak:** Notify safety personnel, evacuate area for large spills, remove all heat and ignition sources, and provide maximum explosion-proof ventilation. Cleanup personnel should protect against vapor inhalation and liquid contact. Clean up spills promptly to reduce fire or vapor hazards. Use a noncombustible absorbent material to pick up small spills or residues. For large spills, dike far ahead to contain. Pick up liquid for reclamation or disposal. Do not release to sewers or waterways due to health and fire and/or explosion hazard. Follow applicable OSHA regulations (29 CFR 1910.120). Diesel fuel oil No. 2-D spills may be environmental hazards. Report large spills.

**Disposal:** Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**EPA Designations**

RCRA Hazardous Waste (40 CFR 261.21): Ignitable waste

CERCLA Hazardous Substance (40 CFR 302.4): Not listed

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

SARA Toxic Chemical (40 CFR 372.65): Not listed

**OSHA Designations**

Air Contaminant (29 CFR 1910.1000, Subpart Z): Not listed

**Section 8. Special Protection Data**

**Goggles:** Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133).

**Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, use a NIOSH-approved respirator with a mist filter and organic vapor cartridge. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*

**Other:** Wear impervious gloves, boots, aprons, and gauntlets to prevent skin contact.

**Ventilation:** Provide general and local explosion-proof ventilation systems to maintain airborne concentrations that promote worker safety and productivity. Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup>

**Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

**Contaminated Equipment:** Never wear contact lenses in the work area: soft lenses may absorb, and all lenses concentrate, irritants. Remove this material from your shoes and equipment. Launder contaminated clothing before wearing.

**Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Section 9. Special Precautions and Comments**

**Storage Requirements:** Use and storage conditions should be suitable for a OSHA Class II combustible liquid. Store in closed containers in a well-ventilated area away from heat and ignition sources and strong oxidizing agents. Protect containers from physical damage. To prevent static sparks, electrically ground and bond all containers and equipment used in shipping, receiving, or transferring operations. Use nonsparking tools and explosion-proof electrical equipment. No smoking in storage or use areas.

**Engineering Controls:** Avoid vapor or mist inhalation and prolonged skin contact. Wear protective rubber gloves and chemical safety glasses where contact with liquid or high mist concentration may occur. Additional suitable protective clothing may be required depending on working conditions. Institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation. Practice good personal hygiene and housekeeping procedures. Do not wear oil contaminated clothing. At least weekly laundering of work clothes is recommended. Do not put oily rags in pockets. When working with this material, wear gloves or use barrier cream.

**Transportation Data (49 CFR 172.101)**

DOT Shipping Name: Fuel oil

DOT Hazard Class: Combustible liquid

ID No.: NA1993

DOT Label: None

DOT Packaging Exceptions: 173.118a

DOT Packaging Requirements: None

**MSDS Collection References:** 1, 6, 7, 12, 73, 84, 101, 103, 126, 127, 132, 133, 136, 143, 146

**Prepared by:** MJ Allison, BS; **Industrial Hygiene Review:** DJ Wilson, CIH; **Medical Review:** AC Darlington, MD; **Edited by:** JR Stuart, MS



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## Material Safety Data Sheets Collection:

Sheet No. 683

### Polychlorinated Biphenyls (PCBs)

Issued: 11/88

Revision: A, 9/92

#### Section 1. Material Identification

39

**Polychlorinated Biphenyls** [ $C_{12}H_{10-n}Cl_n$  ( $n=3, 4, 5$ )] **Description:** A class of nonpolar chlorinated hydrocarbons with a biphenyl nucleus (two benzene nuclei connected by a single C-C bond) in which any or all of the hydrogen atoms have been replaced by chlorine. Commercial PCBs are mixtures of chlorinated biphenyl isomers with varying degrees of chlorination. Prepared industrially by the chlorination of biphenyl with anhydrous chlorine in the presence of a catalyst such as ferric chloride or iron filings. Except for limited research and development applications, PCBs have not been produced in the US since 1977. When large quantities of PCBs were manufactured in the US, they were marketed under the tradename Aroclor (Monsanto) and were characterized by four digit numbers. The first two digits indicating biphenyls (12), triphenyls (54), or both (25, 44); the last two digits indicating the weight percent of chlorine. PCBs' thermal stability, nonflammability, and high dielectric capability made them very useful in electrical equipment. Formerly used as additives in hydraulic fluids, heat transfer systems, lubricants, cutting oils, printer's ink, fire retardants, asphalt, brake linings, automobile body sealants, plasticizers, adhesives, synthetic rubber, floor tile, wax extenders, dedusting agents, pesticide extenders, and carbonless reproducing paper. PCBs are still used in certain existing electrical capacitors and transformers that require enhanced electrical protection to avoid heating from sustained electric faults.

**Other Designations:** CAS No. 1336-36-3, Aroclor, Clophen, Chlorextol, chlorinated biphenyls, chlorinated diphenyl, chlorinated diphenylene, chloro biphenyl, chloro-1,1-biphenyl, Dykanol, Fenclor, Inerteen, Kaneclor, Montar, Noflamol, Phenoclor, Pyralene, Pyranol, Santotherm, Sovol, Therminol FR-1

**Cautions:** PCBs are potent liver toxins that may be absorbed through skin. Potentially, chronic or delayed toxicity is significant because PCBs accumulate in fatty tissue and may reasonably be anticipated to be carcinogens. PCBs are a bioaccumulative environmental hazard. When burned, decomposition products may be more hazardous than the PCBs.

R	1	NFPA
I	4	1
S	3*	0
K	1	-
* Skin absorption		
HMIS		
H	2†	
F	1	
R	0	
PPE†		
† Sec. 8		
† Chronic Effects		

#### Section 2. Ingredients and Occupational Exposure Limits

PCBs, contain various levels of polychlorinated dibenzofurans and chlorinated naphthalenes as contaminants

##### 1991 OSHA PELs, Skin

8-hr TWA (Chlorodiphenyl, 42% chlorine): 1 mg/m<sup>3</sup>  
8-hr TWA (Chlorodiphenyl, 54% chlorine): 0.5 mg/m<sup>3</sup>

##### 1990 DFG (Germany) MAK, Danger of Cutaneous Absorption

TWA (Chlorodiphenyl, 42% chlorine): 0.1 ppm (1 mg/m<sup>3</sup>)  
Category III: Substances with systemic effects, onset of effect > 2 hr., half-life > shift length (strongly cumulative)  
Short-term Level: 1 ppm, 30 min., average value, 1 per shift  
TWA (Chlorodiphenyl, 54% chlorine): 0.05 ppm (0.5 mg/m<sup>3</sup>)  
Category III: (see above)  
Short-term Level: 0.5 ppm, 30 min., average value, 1 per shift

##### 1985-86 Toxicity Data\*

Rat, oral, TD: 1250 mg/kg administered intermittently for 25 weeks produced liver tumors.

Mammal, oral, TD<sub>01</sub>: 325 mg/kg administered to female for 30 days prior to mating and from the 1st to the 36th day of gestation produced effects on newborn (stillbirth; live birth index; viability index).

##### 1990 NIOSH REL

TWA (Chlorodiphenyl, 42% chlorine): 0.001 mg/m<sup>3</sup>  
TWA (Chlorodiphenyl, 54% chlorine): 0.001 mg/m<sup>3</sup>

##### 1992-93 ACGIH TLVs, Skin \*

TWA (Chlorodiphenyl, 42% chlorine): 1 mg/m<sup>3</sup>  
TWA (Chlorodiphenyl, 54% chlorine): 0.5 mg/m<sup>3</sup>

\* These guidelines offer reasonably good protection against systemic intoxication, but may not guarantee that chloroacne won't occur.

† See NIOSH, RTECS (TQ1350000), for additional reproductive, tumorigenic, and toxicity data.

#### Section 3. Physical Data\*

**Boiling Point:** 644-707 F (340-375 C)  
**Melting Point:** 42%: -2.2 F (-19 C); 54%: 14 F (-10 C)  
**Vapor Pressure:** 1 mm Hg at 100 F (38 C); 10<sup>-6</sup> to 10<sup>-3</sup> mm at 20 C  
**Molecular Weight:** 188.7 to 398.5

**Specific Gravity:** 1.3 to 1.8 at 20 C  
**Water Solubility:** Low solubility (0.007 to 5.9 mg/L)  
**Other Solubilities:** Most common organic solvents, oils, and fats; slightly soluble in glycerol and glycols.

**Appearance and Odor:** PCBs vary from mobile oily liquids to white crystalline solids and hard non-crystalline resins, depending upon chlorine content.

\* Physical and chemical properties vary widely according to degree and to the position of chlorination.

#### Section 4. Fire and Explosion Data

**Flash Point:** 286-385 F (141-196 C) OC\* | **Autoignition Temperature:** 464 F (240 C) | **LEL:** None reported | **UEL:** None reported

**Extinguishing Media:** Use extinguishing media suitable to the surrounding fire. Use dry chemical, foam, carbon dioxide (CO<sub>2</sub>), or water spray. Water spray may be ineffective. Use water spray to cool fire-exposed containers or transformers. Do not scatter PCBs with high-pressure water streams. **Unusual Fire or Explosion Hazards:** Combustion products (hydrogen chloride, phosgene, polychlorinated dibenzofurans, and furans) are more hazardous than the PCBs themselves. **Special Fire-fighting Procedures:** Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Approach fire from upwind to avoid highly toxic decomposition products. Structural firefighter's protective clothing will provide limited protection. Do not release runoff from fire control methods to sewers or waterways. Dike for later disposal.

\* Flash points shown are a range for various PCBs. Some forms do not have flash points.

#### Section 5. Reactivity Data

**Stability/Polymerization:** PCBs are very stable materials but are subject to photodechlorination when exposed to sunlight or UV (spectral region above 290 nanometers). Hazardous polymerization cannot occur. **Chemical Incompatibilities:** PCBs are chemically inert and resistant to oxidation, acids, and bases. **Conditions to Avoid:** Avoid heat and ignition sources.

**Hazardous Products of Decomposition:** Thermal oxidative decomposition [1112-1202 F (600-650 C)] of PCBs can produce highly toxic derivatives, including polychlorinated dibenzo-para-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), hydrogen chloride, phosgene and other irritants.

**Section 6. Health Hazard Data**

**Carcinogenicity:** The IARC,<sup>(164)</sup> and NTP<sup>(169)</sup> list PCBs as an IARC probable carcinogen (overall evaluation is 2A; limited human data; sufficient animal data) and NTP anticipated carcinogen, respectively. **Summary of Risks:** PCBs are potent liver toxins that can be absorbed through unbroken skin in toxic amounts without immediate pain or irritation. PCBs have low acute toxicity, but can accumulate in fatty tissue and severe health effects may develop later. Generally, toxicity increases with a higher chlorine content; PCB-oxides are more toxic. The toxic action on the liver also increases with simultaneous exposure to other liver toxins, e.g. chlorinated solvents, alcohol, and certain drugs. Pathological pregnancies (abnormal pigmentations, abortions, stillbirths, and underweight births) have been associated with increased PCB serum levels in mothers; PCBs can be passed in breast milk. PCBs can affect the reproductive system of adults. **Medical Conditions Aggravated by Long-Term Exposure:** Skin, liver, and respiratory disease. **Target Organs:** Skin, liver, eyes, mucous membranes, and respiratory tract. **Primary Entry Routes:** Inhalation, dermal contact, ingestion. **Acute Effects:** Exposure to PCB vapor or mist is severely irritating to the skin, eyes, nose, throat, and upper respiratory tract. Intense acute exposure to high concentrations may result in eye, lung, and liver injury. Systemic effects include nausea, vomiting, increased blood pressure, fatigue, weight loss, jaundice, edema and abdominal pain. Cognitive, neurobehavior and psychomotor impairment and memory loss have also been seen after acute exposure. **Chronic Effects:** Repeated exposure to PCBs can cause chloroacne; redness, swelling, dryness, thickening and darkening of the skin and nails; swelling and burning of the eyes, and excessive eye discharge; distinctive hair follicles; gastrointestinal disturbances; neurological symptoms including headache, dizziness, depression, nervousness, numbness of the extremities, and joint and muscle pain; liver enlargement; menstrual changes in women; and chronic bronchitis. Cancer, primarily liver, is also a possible result of exposure, but data is inconclusive.

**FIRST AID** **Eyes:** Do not allow victim to rub or keep eyes tightly shut. Rinsing eyes with medical oil (olive, mineral) initially may remove PCB and halt irritation better than water rinsing alone. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** Quickly remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. *Multiple soap and water washings are necessary.* Avoid the use of organic solvents to clean the skin. For reddened or blistered skin, consult a physician. **Inhalation:** Remove exposed person to fresh air and support breathing as needed. **Ingestion:** In most cases, accidental PCB ingestion will not be recognized until long after vomiting would be of any value. Never give anything by mouth to an unconscious or convulsing person. Vomiting of the pure substance may cause aspiration. Consult a physician. **Note to Physicians:** Monitor patients for increased hepatic enzymes, chloroacne, and eye, gastrointestinal, and neurologic symptoms listed above. Diagnostic tests include blood levels of PCBs and altered liver enzymes.

**Section 7. Spill, Leak, and Disposal Procedures**

**Spill/Leak:** Notify safety personnel, evacuate all unnecessary personnel, provide adequate ventilation, and isolate hazard area. Cleanup personnel should protect against vapor inhalation and skin or eye contact. For small spills, take up with sand or other noncombustible material and place into containers for later disposal. For larger spills, dike far ahead of spill to contain for later disposal. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Transport:** PCBs have been shown to bio-concentrate significantly in aquatic organisms. **Ecotoxicity:** Bluegill, TLM: 0.278 ppm/96 hr. Mallard Duck, LD<sub>50</sub>: 2000 ppm. **Environmental Degradation:** In general, the persistence of PCBs increases with an increase degree of chlorination. **Soil Absorption/Mobility:** PCBs are tightly absorbed in soil and generally do not leach significantly in most aqueous soil systems. However, in the presence of organic solvents, PCBs may leach rapidly through the soil. Volatilization of PCBs from soil may be slow, but over time may be significant. **Disposal:** Approved PCB disposal methods include: incineration with scrubbing, high-efficiency boilers, landfills, and EPA-approved alternative disposal methods. Each disposal method has various criteria. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**EPA Designations**

RCRA Hazardous Waste (40 CFR 261.33): Not listed  
SARA Extremely Hazardous Substance (40 CFR 355): Not listed  
Listed as a SARA Toxic Chemical (40 CFR 372.65)  
Listed as a CERCLA Hazardous Substance\* (40 CFR 302.4): Final Reportable Quantity (RQ), 1 lb (0.454 kg) [\* per CWA, Sec. 311(b)(4) and 307(a)]

**OSHA Designations**

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

**Section 8. Special Protection Data**

**Goggles:** Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. Minimum respiratory protection should include a combination dust-fume-mist and organic vapor cartridge or canister or air-supplied, depending upon the situation. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets to prevent all skin contact. Butyl rubber, neoprene, Teflon, and fluorocarbon rubber have break through times greater than 8 hrs. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup> **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Segregate contaminated clothing in such a manner so that there is no direct contact by laundry personnel. Implement quality assurance to ascertain the completeness of the cleaning procedures. Remove this material from your shoes and clean PPE. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Section 9. Special Precautions and Comments**

**Storage Requirements:** Store in a closed, labelled, container in a ventilated area with appropriate air pollution control equipment. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. **Administrative Controls:** Inform employees of the adverse health effects associated with PCBs. Limit access to PCB work areas to authorized personnel. Consider preplacement and periodic medical examinations with emphasis on the skin, liver, lung, and reproductive system. Monitor PCB blood levels. Consider possible effects on the fetus. Keep medical records for the entire length of employment and for the following 30 yrs.

**Transportation Data (49 CFR 172.101)**

**DOT Shipping Name:** Polychlorinated biphenyls  
**DOT Hazard Class:** 9  
**ID No.:** UN2315  
**DOT Packing Group:** II  
**DOT Label:** CLASS 9  
**Special Provisions (172.102):** 9, N81

**Packaging Authorizations**

- a) Exceptions: 173.155
- b) Non-bulk Packaging: 173.202
- c) Bulk Packaging: 173.241

**Quantity Limitations**

- a) Passenger Aircraft or Railcar: 100 L
  - b) Cargo Aircraft Only: 220 L
- Vessel Stowage Requirements**
- a) Vessel Stowage: A
  - b) Other: 34

**MSDS Collection References:** 26, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 163, 164, 168, 169, 174, 175, 180

**Prepared by:** MJ Wurth, BS; **Industrial Hygiene Review:** PA Roy MPH, CIH; **Medical Review:** AC Darlington, MD



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**Material Safety Data Sheets Collection:**

Sheet No. 354  
Methyl Alcohol

Issued: 11/77

Revision: D, 11/91

**Section 1. Material Identification**

**Methyl alcohol (CH<sub>3</sub>OH) Description:** Derived from destructive distillation of wood, oxidation of hydrocarbons, or high-pressure catalytic synthesis from hydrogen and carbon dioxide or carbon monoxide. Used as a solvent in manufacturing industrial chemicals and chemical pharmaceuticals, a raw material for making formaldehyde and methyl esters, a softening agent for pyroxylin plastics, a dehydrator for natural gas, a feedstock for manufacturing synthetic proteins by continuous fermentation, an octane booster in gasoline, an extractant for animal and vegetable oils; in antifreeze for automotive radiators, air brakes, gasoline, and diesel oil; and in denaturing ethanol.

**Other Designations:** CAS No. 67-56-1, carbinol, Columbian spirits, methanol, methyl hydroxide, methylol, monohydroxymethane, pyroxylic spirit, wood alcohol, wood naphtha, wood spirit.

**Manufacturer:** Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*<sup>(73)</sup> for a suppliers list.

R 1  
I 2  
S 1\*  
K 4  
\* Skin  
absorption

36  
NFPA  
1 3 0  
HMIS  
H 2  
F 3  
R 0  
PPG†  
† Sec. 8

**Cautions:** Methyl alcohol is moderately toxic by ingestion and mildly toxic by inhalation and skin absorption. It is flammable, volatile, and a dangerous fire hazard.

**Section 2. Ingredients and Occupational Exposure Limits**

Methyl alcohol, ca 100%

**1990 OSHA PELs (Skin)**

8-hr TWA: 200 ppm (260 mg/m<sup>3</sup>)

15-min STEL: 250 ppm (310 mg/m<sup>3</sup>)

**1990 IDLH Level**

25,000 ppm

**1991-92 ACGIH TLVs (Skin)**

TWA: 200 ppm (262 mg/m<sup>3</sup>)

STEL: 250 ppm (328 mg/m<sup>3</sup>)

**1990 DFG (Germany) MAK**

200 ppm (260 mg/m<sup>3</sup>)

**1990 NIOSH RELs (Skin)**

TWA: 200 ppm (260 mg/m<sup>3</sup>)

Ceiling: 250 ppm (325 mg/m<sup>3</sup>)

**1985-86 Toxicity Data\***

Human, inhalation, TC<sub>50</sub>: 300 ppm caused eye (visual field change), CNS (headache), and pulmonary effects

Human, oral, LD<sub>50</sub>: 428 mg/kg causes CNS (headache) and pulmonary (respiratory change) effects

Rat, oral, TD<sub>01</sub>: 7500 mg/kg administered continuously to the female during the 17th to 19th day of gestation produced behavioral effects on newborns

Rat, inhalation, TC<sub>01</sub>: 20,000 ppm/7 hr administered continuously to the female during the 1st to 22nd day of gestation produced specific developmental abnormalities

\* See NIOSH, RTECS (PC1400000), for additional toxicity data.

**Section 3. Physical Data**

**Boiling Point:** 148 °F (64.5 °C)

**Freezing Point:** -144.04 °F (-97.8 °C)

**Vapor Pressure:** 29 mm Hg at 68 °F (20 °C)

**Vapor Density (air = 1):** 1.11

**Viscosity:** 0.00593 P at 68 °F (20 °C)

**Molecular Weight:** 32.05

**Density:** 0.7924 at 68 °F (20 °C)

**Water Solubility:** Soluble

**Other Solubilities:** Soluble in ethanol, ether, benzene, ketones, and most organic solvents

**Appearance and Odor:** Clear, colorless, volatile liquid with a slight alcohol odor when pure, a disagreeably pungent odor when crude, and a low 10-ppm odor threshold.

**Section 4. Fire and Explosion Data**

**Flash Point:** 54 °F (12 °C), CC

**Autoignition Temperature:** 878 °F (470 °C)

**LEL:** 6% v/v

**UEL:** 36.5% v/v

**Extinguishing Media:** For small fires, use dry chemical, carbon dioxide (CO<sub>2</sub>), water spray, or alcohol-resistant foam. For large fires, use water spray, fog, or alcohol-resistant foam. Do not scatter material with any more water than needed to extinguish fire.

**Unusual Fire or Explosion Hazards:** Methyl alcohol is a dangerous fire hazard when exposed to heat, flame, or oxidizers. It is explosive in its vapor form when exposed to heat or flame. Vapors may travel to an ignition source and flash back.

**Special Fire-fighting Procedures:** Since fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Also, wear full protective clothing. Structural firefighters' protective clothing is *ineffective* for fires involving methyl alcohol. If possible without risk, remove container from fire area. Apply cooling water to sides of fire-exposed container until fire is well out. Stay away from ends of tanks. Leave area immediately if you hear a rising sound from venting safety device or see any tank discoloration due to fire. Be aware of runoff from fire control methods. Do not release to sewers or waterways.

**Section 5. Reactivity Data**

**Stability/Polymerization:** Methyl alcohol is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur.

**Chemical Incompatibilities:** Methyl alcohol is incompatible with beryllium dihydride, metals (such as potassium or magnesium), oxidants (such as barium perchlorate, bromine, chlorine, hydrogen peroxide, and sodium hypochlorite), potassium tertbutoxide, carbon tetrachloride + metals; reacts explosively with chloroform + heat, and diethyl zinc; and reacts violently with alkyl aluminum salts, acetyl bromide, chloroform + sodium hydroxide, cyanuric chloride, and nitric acid.

**Conditions to Avoid:** Avoid vapor inhalation and contact with oxidizers and other incompatibles.

**Hazardous Products of Decomposition:** Thermal oxidative decomposition of methyl alcohol can produce carbon oxides (CO and CO<sub>2</sub>), possible formaldehyde (HCHO) and acrid smoke, and irritating fumes.

**Section 6. Health Hazard Data**

**Carcinogenicity:** In 1990 reports, the IARC, NTP, and OSHA do not list methyl alcohol as a carcinogen.

**Summary of Risks:** Methyl alcohol is toxic mainly to the nervous system, particularly optic nerves, where damage can progress to permanent blindness. Poisoning may also result in metabolic acidosis. Methyl alcohol oxidizes in the body to form formaldehyde and formic acid. These derivatives are believed responsible for many of methyl alcohol's poisonous and toxic effects. Since it is eliminated slowly from the body, methyl alcohol is considered a cumulative poison. The fatal ingestion dose is 100 to 250 ml, although death is reported from less than 33 ml.

**Medical Conditions Aggravated by Long-Term Exposure:** None reported

**Target Organs:** Eyes, central nervous system, skin, and digestive tract.

**Primary Entry Routes:** Inhalation, ingestion, skin absorption.

**Acute effects:** Inhalation can cause irritation of eyes and nose, headache, fatigue, nausea, visual impairment (optic nerve neuropathy or visual field changes) or complete and possibly permanent blindness, acidosis, convulsions, circulatory collapse, respiratory failure, and death. Ingestion can cause gastrointestinal (GI) irritation followed by the symptoms described for inhalation and possible kidney impairment. Skin contact results in a feeling of coldness, dryness, and cracking possibly leading to dermatitis. Methyl alcohol can absorb through skin and may cause headache, fatigue, and visual disturbances. Eye contact causes irritation and watering of eyes, inflamed lids, and painful sensitization to light.

**Chronic Effects:** Chronic inhalation or skin absorption may produce visual impairment or complete blindness.

**FIRST AID**

**Eyes:** Gently lift the eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Do not let victim rub or keep eyes tightly shut. Consult a physician immediately.

**Skin:** Quickly remove contaminated clothing. Since methyl alcohol is volatile and flammable, carefully dispose of contaminated clothing. Rinse with flooding amounts of water for at least 15 min. For reddened or blistered skin, consult a physician. Wash affected area with soap and water.

**Inhalation:** Remove exposed person to fresh air and support breathing as needed.

**Ingestion:** Never give anything by mouth to an unconscious or convulsing person. If ingested, have that *conscious and alert* person drink 1 to 2 glasses of water, then induce vomiting.

**After first aid, get appropriate in-plant, paramedic, or community medical support.**

**Note to Physicians:** Consider administering 10% ethanol in D5W intravenously to maintain ethyl alcohol blood level at 100 mg/dl. Check formic acid in urine and measure blood pH and plasma bicarbonate. After ingestion, there is typically an 18- to 48-hr latency period before clinical toxicity

**Section 7. Spill, Leak, and Disposal Procedures**

**Spill/Leak:** Notify safety personnel, isolate area, deny entry, and stay upwind. Shut off all ignition sources—no flares, smoking, or flames in hazard area. Cleanup personnel should wear fully encapsulating, vapor-protective clothing for spills or leaks with no fire. Water spray may reduce vapor, but not prevent ignition in closed spaces. For small spills, use nonsparking tools to take up with earth, sand, vermiculite, or other absorbent, noncombustible material and place in suitable containers for later disposal. For large spills, dike far ahead of spill and await disposal. Follow applicable OSHA regulations (29 CFR 1910.120).

**Environmental Degradation:** Aquatic toxicity rating: TLm 96, over 1000 ppm.

**Disposal:** Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**EPA Designations**

Listed as a RCRA Hazardous Waste (40 CFR 261.33): Hazardous Waste No. U154

CERCLA Hazardous Substance (40 CFR 302.4): Not listed

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

SARA Toxic Chemical (40 CFR 372.65): Not listed

**OSHA Designations**

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

**Section 8. Special Protection Data**

**Goggles:** Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Since contact lens use in industry is controversial, establish your own policy.

**Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a NIOSH-approved respirator. Select the respirator based on its suitability to provide adequate worker protection for the given working conditions, level of airborne contamination, and presence of sufficient oxygen. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.*

**Other:** Wear impervious gloves, boots, aprons, and gauntlets to prevent all skin contact.

**Ventilation:** Provide general and local explosion-proof exhaust ventilation systems to maintain airborne concentrations below the OSHA PELs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup>

**Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

**Contaminated Equipment:** Separate contaminated work clothes from street clothes. Launder contaminated work clothing before wearing. Remove this material from your shoes and clean personal protective equipment.

**Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Section 9. Special Precautions and Comments**

**Storage Requirements:** Avoid physical damage to containers. Store in cool, dry, well-ventilated flammables storage area, away from strong oxidizers and other incompatibles. To prevent static sparks, electrically ground all equipment used in methyl alcohol storage, manufacture, and transportation. Use nonsparking tools.

**Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control hazardous airborne contaminants and to maintain concentrations at the lowest practical level.

**Other Precautions:** Consider preplacement and periodic medical examinations of exposed workers emphasizing neurological, kidney, liver, and visual function. Practice good personal hygiene and housekeeping procedures. If respirators are used, institute a respiratory protection program that includes regular training, maintenance, inspection, and evaluation.

**Transportation Data (49 CFR 172.101, .102)**

**DOT Shipping Name:** Methyl alcohol

**DOT Hazard Class:** Flammable liquid

**ID No.:** UN1230

**DOT Label:** Flammable liquid

**DOT Packaging Exceptions:** 173.118

**DOT Packaging Requirements:** 173.119

**IMO Shipping Name:** Methanol

**IMO Hazard Class:** 3.2

**ID No.:** UN1230

**IMO Label:** Flammable Liquid, Poison

**IMDG Packaging Group:** II

**MSDS Collection References:** 26, 38, 73, 89, 100, 101, 103, 124, 126, 127, 132, 133, 136, 140, 143, 146, 148, 149, 153, 159, 163

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## Material Safety Data Sheets Collection

Isopropyl Alcohol

MSDS No. 324

Date of Preparation: 9/85

Revision: A, 10/93

### Section 1 - Chemical Product and Company Identification

42

**Product/Chemical Name:** Isopropyl Alcohol

**Chemical Formula:**  $(\text{CH}_3)_2\text{CHOH}$

**CAS No.:** 67-63-0

**Synonyms:** Dimethyl carbinol, 2-hydroxypropane, IPA, Isohol, Lutosol, isopropanol, Petrohol, 2-propanol, *sec*-propyl alcohol, rubbing alcohol, Spectrar.

**Derivation:** Treating propylene with sulfuric acid and then hydrolyzing or direct hydration of propylene using superheated steam. Most commonly available as rubbing alcohol (70% IPA).

**General Use:** As a solvent for gums, shellac, and essential oils, chemical intermediate, dehydrating agent, vehicle for germicidal compounds, de-icing agent for liquid fuels; for denaturing ethyl alcohol, preserving pathological specimens; in extraction of alkaloids, quick-drying inks and oils, and an ingredient of skin lotions, cosmetics, window cleaner, liquid soaps, and pharmaceuticals.

**Vendors:** Consult the latest *Chemical Week Buyers' Guide*. (73)

### Section 2 - Composition / Information on Ingredients

Isopropyl alcohol, 100% vol. Most commonly sold as 70% isopropyl alcohol (rubbing alcohol).

#### OSHA PELs

8-hr TWA: 400 ppm (980 mg/m<sup>3</sup>)

STEL: 500 ppm (1225 mg/m<sup>3</sup>) \*

#### ACGIH TLVs

TWA: 400 ppm (983 mg/m<sup>3</sup>)

STEL: 500 ppm (1230 mg/m<sup>3</sup>)

#### NIOSH REL

10-hr TWA: 400 ppm (980 mg/m<sup>3</sup>)

STEL: 500 ppm (1225 mg/m<sup>3</sup>)

#### IDLH Level

12,000 ppm

#### DFG (Germany) MAK

TWA: 400 ppm (980 mg/m<sup>3</sup>)

Category II: Substances with systemic effects

Half-life: < 2 hr

**Peak Exposure Limit:** 800 ppm, 30 min. average value, 4/shift

\* Vacated 1989 Final Rule Limits

### Section 3 - Hazards Identification

#### ☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Isopropyl alcohol is a highly flammable, volatile liquid. It is considered more toxic than ethyl alcohol, but less toxic than methyl alcohol. Inhalation can cause irritation of the eyes and respiratory tract and central nervous system depression at high concentrations. Repeated skin contact may cause dermatitis. Systemic toxicity appears to occur mostly in cases of heavy ingestion or inhalation. There is recent evidence that skin absorption may be more likely to cause systemic effects than previously thought.

#### Potential Health Effects

**Primary Entry Routes:** Inhalation, ingestion, skin contact/absorption.

**Target Organs:** Eyes, skin, respiratory system.

#### Acute Effects

**Inhalation:** Vapor inhalation is irritating to the respiratory tract and can cause central nervous system depression at high concentrations. Volunteers exposed to 400 ppm for 3 to 5 min experienced mild eye and respiratory irritation. At 800 ppm, irritation was not severe, but most people found the air uncomfortable to breathe.

**Eye:** Exposure to the vapor or direct contact with the liquid causes irritation and possible corneal burns.

**Skin:** Some irritation may occur after prolonged exposure.

**Ingestion:** Accidental ingestions have provided the most information on isopropyl alcohol toxicity. Symptoms include nausea and vomiting, headache, facial flushing, dizziness, lowered blood pressure, mental depression, hallucinations and distorted perceptions, difficulty breathing, respiratory depression, stupor, unconsciousness, and coma. Kidney insufficiency including oliguria (reduced urine excretion), anuria (absent urine excretion), nitrogen retention, and edema (fluid build-up in tissues) may occur. One post-mortem examination in a case of heavy ingestion showed extensive hemorrhagic tracheobronchitis, bronchopneumonia, and hemorrhagic pulmonary edema. Death can occur in 24 to 36 h post-ingestion due to respiratory paralysis.

**Carcinogenicity:** NTP and OSHA do not list isopropyl alcohol as a carcinogen. The IARC has studied IPA and has classified it as Class-3 (unclassifiable, inadequate human and animal evidence). There appears to be an association between the *manufacture* (strong acid process, rather than the alcohol itself) of isopropanol and paranasal cancer, but this may be due to the diisopropyl sulfate or isopropyl oil by-products.

**Medical Conditions Aggravated by Long-Term Exposure:** Dermatitis or respiratory or kidney disorders.

**Chronic Effects:** Repeated skin contact can cause drying of skin and delayed hypersensitivity reactions in some individuals.

#### Wilson Risk Scale

R 1  
I 2  
S 2\*  
K 3

\*Skin absorption

#### HMIS

H 1  
F 3  
R 0

#### PPE †

†Sec. 8

**Other:** Isopropyl alcohol is oxidized in the body to acetone where it is excreted by the lungs or kidneys. Some acetone may be further metabolized to acetate, formate, and finally carbon dioxide. Probable oral lethal dose is 240 mL.

### Section 4 - First Aid Measures

**Inhalation:** Remove exposed person to fresh air and support breathing as needed.

**Eye Contact:** *Do not* allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately.

**Skin Contact:** *Quickly* remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician.

**Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have the *conscious and alert* person drink 1 to 2 glasses of water to dilute. Vomiting may be contraindicated because of the rapid onset of central nervous system depression. Gastric lavage is preferred.

*After first aid, get appropriate in-plant, paramedic, or community medical support.*

**Note to Physicians:** Diagnostic test: acetone in urine.

### Section 5 - Fire Fighting Measures

**Flash Point:** 53 °F (12 °C)

**Flash Point Method:** CC

**Burning Rate:** 2.3 mm/min.

**Autoignition Temperature:** 750°F (399°C)

**LEL:** 2 % v/v

**UEL:** 12.7 % v/v at 200 °F

**Flammability Classification:** Class 1B Flammable Liquid

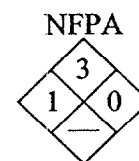
**Extinguishing Media:** Carbon dioxide, dry chemical, water *spray* (solid streams can spread fire), alcohol-resistant foam, or fog.

**Unusual Fire or Explosion Hazards:** Container may explode in heat of fire. Vapors may travel to an ignition source and flash back. Isopropyl alcohol poses an explosion hazard indoors, outdoors, and in sewers.

**Hazardous Combustion Products:** Carbon oxides and acrid smoke.

**Fire-Fighting Instructions:** If possible without risk, move container from fire area. Apply cooling water to container side until well after fire is out. Stay away from ends of tanks. For massive fire in cargo area, use monitor nozzles or unmanned hose holders; if impossible, withdraw and let fire burn. Withdraw immediately if you hear a rising sound from venting safety device or notice any tank discoloration due to fire. *Do not* release runoff from fire control methods to sewers or waterways.

**Fire-Fighting Equipment:** Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides only limited protection.



### Section 6 - Accidental Release Measures

**Spill /Leak Procedures:** Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off ignition sources. Cleanup personnel should protect against vapor inhalation and skin/eye contact. Water spray may reduce vapor, but may not prevent ignition in closed spaces.

**Small Spills:** Take up with earth, sand, vermiculite, or other absorbent, noncombustible material and place in suitable containers.

**Large Spills**

**Containment:** For large spills, dike far ahead of liquid spill for later disposal. Do not release into sewers or waterways.

**Regulatory Requirements:** Follow applicable OSHA regulations (29 CFR 1910.120).

### Section 7 - Handling and Storage

**Handling Precautions:** Use non-sparking tools to open containers.

**Storage Requirements:** Store in a cool, dry, well-ventilated area away from heat, ignition sources, and incompatibles (Sec 10). Install electrical equipment of Class I, Group D.

### Section 8 - Exposure Controls / Personal Protection

**Engineering Controls:** To prevent static sparks, electrically ground and bond all equipment used with and around IPA.

**Ventilation:** Provide general or local exhaust ventilation systems to maintain airborne levels below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred since it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup>

**Administrative Controls:** Consider preplacement and periodic medical exams of exposed workers with emphasis on the skin, kidneys, and respiratory system. Be extra cautious when using IPA concurrently with carbon tetrachloride because animal studies have shown it enhances carbon tetrachloride's toxicity.

**Protective Clothing/Equipment:** Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Nitrile rubber (breakthrough time > 8 hr), Neoprene and Teflon (breakthrough time > 4 hr) are suitable materials for PPE. Do not use PVA, PVC or natural rubber (breakthrough time < 1 hr). Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy.



**Respiratory Protection:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For < 1000 ppm, use any powered, air purifying respirator with organic vapor cartridges or any chemical cartridge respirator with a full facepiece and organic vapor cartridge(s). For < 10,000 ppm, use any supplied-air respirator (SAR) operated in continuous-flow mode. For < 12,000 ppm, use any air-purifying, full facepiece respirator (gas mask) with a chin-style, front-or back-mounted organic vapor canister or any SCBA or SAR with a full facepiece. For emergency or entrance into unknown concentrations, use any SCBA or SAR (with auxiliary SCBA) with a full facepiece and operated in pressure-demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. *Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.* If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas.

**Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities.

**Contaminated Equipment:** Separate contaminated work clothes from street clothes. Launder before reuse. Remove isopropyl alcohol from your shoes and clean personal protective equipment.

**Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using isopropyl alcohol, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

### Section 9 - Physical and Chemical Properties

**Physical State:** Liquid

**Appearance and Odor:** Colorless with a slight odor and bitter taste.

**Odor Threshold:** 22 ppm\*

**Vapor Pressure:** 44 mm Hg at 25 °F (77 °C)

**Saturated Vapor Density** (Air = 1.2 kg/m<sup>3</sup>, 0.075 lb/ft<sup>3</sup>):  
1.274 kg/m<sup>3</sup> or 0.080 lb/ft<sup>3</sup>

**Formula Weight:** 60.09

**Density** (H<sub>2</sub>O=1, at 4 °C): 0.78505 at 68°F (20 °C)

**Water Solubility:** > 10 %

**Ionization Potential:** 10.10 eV

**Other Solubilities:** Soluble in alcohol, ether, chloroform, and benzene. Insoluble in salt solutions.

**Boiling Point:** 180.5 °F (82.5 °C)

**Freezing Point:** -129.1 °F (-89.5 °C)

**Viscosity:** 2.1 cP at 77 °F (25 °C)

**Refraction Index:** 1.375 at 68 °F (20 °C)

**Surface Tension:** 20.8 dyne/cm at 77 °F (25 °C)

**Critical Temperature:** 455 °F (235 °C)

**Critical Pressure:** 47 atm

**Octanol/Water Partition Coefficient:** log K<sub>ow</sub> = 0.05

\* References range from 1 to as high as 610 ppm.

### Section 10 - Stability and Reactivity

**Stability:** Isopropyl alcohol is stable at room temperature in closed containers under normal storage and handling conditions.

**Polymerization:** Hazardous polymerization does not occur.

**Chemical Incompatibilities:** Include acetaldehyde, chlorine, ethylene oxide, acids and isocyanates, hydrogen + palladium, nitroform, oleum, phosgene, potassium *t*-butoxide, oxygen (forms unstable peroxides), trinitromethane, barium perchlorate, tetrafluoroborate, chromium trioxide, sodium dichromate + sulfuric acid, aluminum, aluminum triisopropoxide, and oxidizers. Will attack some forms of plastic, rubber, and coatings.

**Conditions to Avoid:** Exposure to heat, ignition sources, and incompatibles.

**Hazardous Decomposition Products:** Thermal oxidative decomposition of isopropyl alcohol can produce carbon oxides and acrid smoke.

### Section 11 - Toxicological Information

#### Toxicity Data:\*

#### Eye Effects:

Rabbit, eye: 100 mg caused severe irritation.

#### Skin Effects:

Rabbit, skin: 500 mg caused mild irritation.

#### Reproductive:

Rat, inhalation: 3500 ppm/7 hr given from 1 to 19 days of pregnancy caused fetotoxicity.

#### Acute Oral Effects:

Human, oral, TD<sub>Lo</sub>: 223 mg/kg caused hallucinations, distorted perceptions, lowered blood pressure, and a change in pulse rate.

Human, oral, LD<sub>Lo</sub>: 3570 mg/kg caused coma, respiratory depression, nausea, and vomiting.

Rat, oral, LD<sub>50</sub>: 5045 mg/kg caused a change in righting reflex, and somnolence (general depressed activity).

\* See NIOSH, RTECS (NT8050000), for additional toxicity data.

### Section 12 - Ecological Information

**Ecotoxicity:** Guppies (*Poecilia reticulata*) LC<sub>50</sub> = 7,060 ppm/7 days; fathead minnow (*Pimephales promelas*) LC<sub>50</sub> = 11,830 mg/L/1 hr. BOD = 133 %/5 days.

**Environmental Degradation:** On soil, IPA will volatilize or leach into groundwater. Biodegradation is possible but rates are not found in available literature. It will volatilize (est. half-life = 5.4 days) or biodegrade in water. It is not expected to bioconcentrate in fish. In the air, it reacts with photochemically produced hydroxyl radicals with a half-life of one to several days. Because it is soluble, removal by rain, snow or other precipitation is possible.

### Section 13 - Disposal Considerations

**Disposal:** Microbial degradation is possible by oxidizing isopropyl alcohol to acetone by members of the genus *Desulfovibrio*. Spray waste into incinerator (permit-approved facilities only) equipped with an afterburner and scrubber. Isopropyl alcohol can be settled out of water spills by salting with sodium chloride. Note: Salt may harm aquatic life, so weigh the benefits against possible harm before application. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**Container Cleaning and Disposal:** Triple rinse containers.

### Section 14 - Transport Information

#### DOT Transportation Data (49 CFR 172.101):

**Shipping Name:** Isopropanol or isopropyl alcohol

**Shipping Symbols:** -

**Hazard Class:** 3

**ID No.:** UN1219

**Packing Group:** II

**Label:** Flammable Liquid

**Special Provisions (172.102):** T1

**Packaging Authorizations**

a) Exceptions: 173.150

b) Non-bulk Packaging: 173.202

c) Bulk Packaging: 173.242

**Quantity Limitations**

a) Passenger, Aircraft, or Railcar: 5 L

b) Cargo Aircraft Only: 60 L

**Vessel Stowage Requirements**

a) Vessel Stowage: B

b) Other: -

### Section 15 - Regulatory Information

**EPA Regulations:**

Listed as a RCRA Hazardous Waste Number (40 CFR 261.21)

RCRA Hazardous Waste Classification (40 CFR 261.21): Characteristic of Ignitability

Listed (Unlisted Hazardous Waste, Characteristic of Ignitability) as a CERCLA Hazardous Substance (40 CFR 302.4) per RCRA, Sec. 3001

CERCLA Reportable Quantity (RQ), 100 lb (45.4 kg)

SARA 311/312 Codes: 1, 2, 3

Listed as a SARA Toxic Chemical (40 CFR 372.65); *only persons who manufacture by the strong acid process are subject; no supplier notification.*

SARA EHS (Extremely Hazardous Substance) (40 CFR 355): Not listed

**OSHA Regulations:**

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1, Z-1-A)

### Section 16 - Other Information

**References:** 73, 103, 124, 126, 127, 132, 136, 139, 148, 153, 159, 164, 167, 168, 176, 187

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## Material Safety Data Sheets Collection:

Sheet No. 397

**n-Hexane**

Issued: 10/78


Revision: D, 9/92

### Section 1. Material Identification

**n-Hexane** ( $\text{CH}_3(\text{CH}_2)_4\text{CH}_3$ ) **Description:** Derived by fractional distillation from petroleum (molecular sieve process). Used as a solvent for glues, cements, adhesives, fats, and oils; a lab reagent; liquid in low temperature thermometers (instead of mercury); thinner, cleaning agent; polymerization reaction medium; an alcohol denaturant; in retreading tires for determining the refraction index of minerals.

**Other Designations:** CAS No. 110-54-3, dipropyl, Gettysolve-B, hexyl hydride, NCI-C60571, Skellysolve-B.

**Manufacturer:** Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*<sup>(73)</sup> for a suppliers list.

R	1		NFPA
I	3		
S	2*		
K	3		
* Skin absorption			
HMIS			
H		2†	
F		3	
R		0	
PPE-Sec. 8			
† Chronic effects			

**Cautions:** *n*-Hexane is highly flammable. It is irritating to the eyes, skin, and mucous membranes. Vapor inhalation produces central nervous system (CNS) depression, becoming anesthetic at high concentrations. Chronic exposure may result in polyneuropathy.

### Section 2. Ingredients and Occupational Exposure Limits

*n*-Hexane; commercial hexane is a mixture of *n*-hexane and isomers of methyl pentane and heptane. 1 to 6% benzene may also be present.

#### 1991 OSHA PEL

8-hr TWA: 50 ppm (180 mg/m<sup>3</sup>)

#### 1992-93 ACGIH TLV

TWA: 50 ppm (176 mg/m<sup>3</sup>)

#### 1985-86 Toxicity Data\*

Human, inhalation,  $\text{TC}_{10}$ : 5000 ppm/10 min caused hallucinations and distorted perceptions.

#### 1990 IDLH Level

5000 ppm

#### 1990 DFG (Germany) MAK

TWA: 50 ppm (180 mg/m<sup>3</sup>)

Rat, oral,  $\text{LD}_{50}$ : 28,710 mg/kg; no toxic effect noted

#### 1990 NIOSH REL

TWA: 50 ppm (180 mg/m<sup>3</sup>)

Category II: substances with systemic effects

Half-life: < 2 hr

Peak Exposure Limit: 100 ppm, 30 min

average value, 4/shift

Rat, inhalation,  $\text{TC}_{10}$ : 1000 ppm/6 hr from the 8th to 16th day of pregnancy produced effects on newborn growth.

Rabbit, eye: 10 mg caused mild irritation.

\* See NIOSH, *RTECS* (MN9275000), for additional irritation, mutation, reproductive, and toxicity data.

### Section 3. Physical Data

**Boiling Point:** 156 °F (69 °C)

**Freezing Point:** -139 °F (-95 °C)

**Vapor Pressure:** 150 mm Hg at 77 °F (25 °C)

**Refraction Index:** 1.37486 at 68 °F (20 °C)

**Critical Temperature:** 453.2 °F (234 °C)

**Critical Pressure:** 29.7 atm

**Liquid Surface Tension:** 18.4 dyne/cm

**Odor Threshold:** 65 ppm

**Molecular Weight:** 86.17

**Density:** 0.66 at 20/4 °C

**Saturated Vapor Density (Air = 0.075 lb/ft<sup>3</sup> or 1.2 kg/m<sup>3</sup>):** 0.1049 lb/ft<sup>3</sup> or 1.678 kg/m<sup>3</sup>

**Water Solubility:** Slightly, 0.014 mg/ml at 68 °F (20 °C)

**Other Solubilities:** Alcohol, acetone, chloroform, ether, and most non-polar solvents.

**Ionization Potential:** 10.18 eV

**Viscosity:** 0.334 cP at 35 °F (2 °C), 0.306 cP at 80 °F (27 °C), 0.276 cP at 145 °F (62.5 °C)

**Appearance and Odor:** A colorless, volatile liquid with a gasoline-like odor.

### Section 4. Fire and Explosion Data

**Flash Point:** -7.6 °F (-22 °C)

**Autoignition Temperature:** 437 °F (225 °C)

**LEL:** 1.2% v/v

**UEL:** 7.5% v/v

**Extinguishing Media:** *n*-Hexane is a Class 1B Flammable Liquid. For small fires, use dry chemical, carbon dioxide, water spray, or regular foam. For large fires, use water spray, fog, or regular foam. **Unusual Fire or Explosion Hazards:** Vapors may travel to an ignition source and flash back. Container may explode in heat of fire. *n*-Hexane poses a vapor explosion hazard indoors, outdoors, and in sewers. Burning rate = 7.3 mm/min.

**Special Fire-fighting Procedures:** Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides only limited protection. If possible without risk, move container from fire area. Apply cooling water to sides of container until well after fire is out. Stay away from ends of tanks. For massive fire in cargo area, use monitor nozzles or unmanned hose holders; if impossible, withdraw from fire and let burn. Withdraw immediately if you hear a rising sound from venting safety device or notice any tank discoloration due to fire. Discoloration may indicate danger of BLEVE (boiling liquid expanding vapor explosion). Do not release runoff from fire control methods to sewers or waterways.

### Section 5. Reactivity Data

**Stability/Polymerization:** *n*-Hexane is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Incompatible with strong oxidizers and may explode at 82.4 °F (28 °C) when mixed with dinitrogen tetroxide. **Conditions to Avoid:** Contact with heat and incompatibles.

**Hazardous Products of Decomposition:** Thermal oxidative decomposition of *n*-hexane can produce acrid smoke and irritating vapors.

### Section 6. Health Hazard Data

**Carcinogenicity:** The IARC,<sup>(164)</sup> NTP,<sup>(169)</sup> and OSHA<sup>(164)</sup> do not list *n*-hexane as a carcinogen. Although there is no data on human carcinogenicity specifically caused by *n*-hexane, there is an increase in association between Leukemia risk in the rubber industry and exposure to a variety of substances including hexane. **Summary of Risks:** Vapors are irritating to the skin, eyes, and respiratory tract. Inhalation produces varying degrees of CNS depression depending on concentration. High concentrations may lead to asphyxia (oxygen displacement). Chronic exposure (usually at least 60 to 240 ppm) results in neurotoxicity characterized by sensory loss, pain, and neurogenic atrophy of skeletal muscle. Peripheral neuropathy is mostly of the 'stocking & glove' type. *n*-Hexane is ultimately converted to 2,5-hexanedione during metabolism and is considered to be the metabolite responsible for toxicity. Evidence exists that *n*-hexane accumulates in fatty tissue which would explain its affinity for the blood, liver, and brain where lipids are prevalent. After exposure has ceased, the half-life is 64 hrs. Metabolism is inhibited by co-exposure to toluene, methylethyl ketone, or methyl *n*-butyl ketone. *n*-Hexane is absorbed through the skin in both liquid and vapor form. Therefore, dermal vapor absorption raises biological levels above those reached during inhalation of or below the TLV concentration. This is why it is imperative that protective clothing be used so that the TLV levels are sufficient to prevent over-exposure. **Medical Conditions Aggravated by Long-Term Exposure:** Skin, CNS, PNS, and respiratory diseases. **Target Organs:** Eyes, skin, respiratory system, central and peripheral nervous system. **Primary Entry Routes:** Inhalation, skin contact/absorption, eyes, ingestion. **Acute Effects:** Vapor inhalation produced marked vertigo and hallucinations at 5000 ppm/10 min; drowsiness, fatigue, appetite loss, and paresthesia in the distal extremities at 1000 to 2500/12 hrs; muscle weakness, cold pulsation in extremities, blurred vision, headache, anorexia and onset of polyneuropathy at 500 to 2500 ppm (time not given).

Continue on next page

**Section 6. Health Hazard Data**

Skin contact causes immediate irritation with redness, painful burning and possible blisters. Eye contact produces irritation, watering, and burning. Ingestion poses a serious aspiration hazard. If aspiration into the lungs occurs, asphyxiation from oxygen displacement may lead to brain damage and cardiac arrest. Cardiac sensitization to epinephrine (the body's adrenalin) may cause rhythm disturbances with potentially fatal consequences. **Chronic Effects:** Polyneuropathy occurs from repeated exposure to levels typically in the 400 to 600 ppm range; there is a case of polyneuropathy after exposure to 54 to 200 ppm/1 year. Initial symptoms include muscle weakness, motor loss, sensation disturbances (numbness and pain without stimulus), and distal symmetric leg pain after 2 to 6 months exposure. Clinical studies indicate muscle atrophy (wasting away), foot drop, decreased muscle tone and strength, and paresthesias of the arms and legs. Vision problems including changes in color vision, retinal pigmentation, and in perifoveal capillaries were found in workers exposed to 420 to 1280 ppm for > 5 years. Progression of neuropathy may continue for several months after exposure has ceased, followed by slow recovery taking on the average of 9 to 10 months and rarely, up to 2 years. Residual spinal cord damage was noted in most severely injured victims.

**FIRST AID Emergency personnel should protect against exposure**

**Eyes:** Do not allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** Quickly remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician.

**Inhalation:** Remove exposed person to fresh air and administer supplemental oxygen as needed. Intubation may be necessary in severe cases (aspiration of liquid). **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center and unless otherwise advised, have that conscious and alert person drink 1 to 2 glasses of water to dilute. Do not induce vomiting because of severe aspiration hazard. If spontaneous vomiting occurs, position head to avoid aspiration of vomitus.

**Note to Physicians:** BEI = 2,5-hexanedione in urine, sample at end of shift at workweeks end, 5 mg/g creatine. Also measure *n*-hexane in expired air. Analgesics may be necessary for pain management, there is no specific antidote. Monitor arterial blood gases in cases of severe aspiration.

**Section 7. Spill, Leak, and Disposal Procedures**

**Spill/Leak:** Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. Shut off ignition sources. Cleanup personnel should protect against vapor inhalation and skin/eye contact. Take up small spills with earth, sand, vermiculite, or other absorbent, noncombustible material and place in suitable containers. Dike far ahead of large spill for later disposal or reclamation. For water spills, use oil skimming equipment to lift spill. Absorbent foams can be applied to slick. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Degradation:** If released on soil, *n*-hexane will readily volatilize from moist surfaces although some may absorb to soil. In water, *n*-hexane will volatilize rapidly although some will absorb to sediment. The log bioconcentration factor (log BCF) estimated at 2.24 to 2.89 suggests bioconcentration is not an important factor in aquatic systems. The estimated Koc of 1250 to 4100 indicates that *n*-hexane absorbs to carbon/organic matter. Volatilization half-life from a model river is 2.7 hr at 77 °F (25 °C), 1 meter deep flowing at 1 m/sec with a 3 m/sec wind speed. Volatilization from a model pond (which considers effect of absorption) is estimated at 6.8 days. In the atmosphere, it is expected to exist entirely in the vapor phase. It does not absorb UV light in the environmentally significant range (> 290 nm). It reacts with photochemically produced hydroxyl radicals. Estimated lifetime under photochemical smog conditions is 5.9 hr (SE England). **Disposal:** Spray into an incinerator (may burn quicker by addition of another flammable solvent). Evaporation in a suitable hood may be used for smaller amounts. Landfill is not recommended. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**EPA Designations**

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

SARA Toxic Chemical (40 CFR 372.65): Not listed

Listed as a RCRA Hazardous Waste (40 CFR 261.21): D001, *Characteristic of ignitability*

Listed as 'Unlisted hazardous Waste, *Characteristic of ignitability*' a CERCLA Hazardous Substance\* (40 CFR 302.4): Final Reportable Quantity (RQ), 100 lb (45.4 kg) [\* per RCRA, Sec. 3001]

**OSHA Designations**

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

**Section 8. Special Protection Data**

**Goggles:** Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. For < 500 ppm, use a supplied-air respirator (SAR) or SCBA. For < 1250 ppm, use a SAR operated in continuous-flow mode. For 2500 ppm, use a SAR with a tight-fitting facepiece operated in continuous-flow mode or a SCBA with a full facepiece. For < 5000 ppm, use a SAR operated pressure demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. **Warning! Air-purifying respirators do not protect workers in oxygen-deficient atmospheres.** If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets made of nitrile, Viton, polyvinyl chloride, or chlorinated polyethylene to prevent skin contact. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below the OSHA PEL (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup> **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes and launder before reuse. Remove this material from your shoes and clean PPE. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Section 9. Special Precautions and Comments**

**Storage Requirements:** Store in a cool, dry, well-ventilated area away from heat, ignition sources, and incompatibles (Sec. 5).

**Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. Purge all vessels previously containing *n*-hexane with steam before entering for the purpose of repair (cutting, welding). Refer to OSHA's Confined Space Standard (29 CFR 1910.119). **Administrative Controls:** Consider preplacement and periodic medical exams of exposed workers that emphasize the central and peripheral nervous systems, skin, eyes, and respiratory system.

**Transportation Data (49 CFR 172.101)**

DOT Shipping Name: Hexanes

DOT Hazard Class: 3

ID No.: UN1208

DOT Packing Group: II

DOT Label: Flammable Liquid

Special Provisions (172.102): T8

Packaging Authorizations

a) Exceptions: 173.150

b) Non-bulk Packaging: 173.202

c) Bulk Packaging: 173.242

Quantity Limitations

a) Passenger Aircraft or Railcar: 5L

b) Cargo Aircraft Only: 60L

Vessel Stowage Requirements

a) Vessel Stowage: E

b) Other:

MSDS Collection References: 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 139, 140, 148, 149, 153, 159, 162, 163, 164, 167, 168, 171, 174

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## Material Safety Data Sheets Collection:

Sheet No. 300  
Acetone

Issued: 11/77

Revision: F, 9/92

### Section 1. Material Identification

39

**Acetone (CH<sub>3</sub>COCH<sub>3</sub>) Description:** Derived by the dehydrogenation or oxidation of isopropyl alcohol with a metallic catalyst, the oxidation of cumene, the vapor phase oxidation of butane; and as a by-product of synthetic glycerol production. Used as a solvent for paint, varnish, lacquer, fat, oil, wax, resin, rubber, plastic, and rubber cement; to clean and dry parts of precision equipment; in the manufacture of chemicals (methyl isobutyl ketone, methyl isobutyl carbinol, methyl methacrylate, bisphenol-A, acetic acid (ketene process), mesityl oxide, diacetone alcohol, chloroform, iodoform, bromoform), explosives, aeroplane dopes, rayon, photographic films, isoprene; acetylene gas storage cylinders; in purifying paraffin; in nail polish remover; in the extraction of various principles from animal and plant substances; in hardening and dehydrating tissues; in cellulose acetate (especially as spinning solvent); as a solvent for potassium iodide and permanganate; as a delusterant for cellulose acetate fibers; in the specification testing of vulcanized rubber products.

**Other Designations:** CAS No. 67-64-1, A13-01238, Chevron acetone, dimethylformaldehyde, dimethylketal, dimethyl ketone,  $\beta$ -ketopropane, methyl ketone, propanone, 2-propanone, pyroacetic acid, pyroacetic ether.

**Manufacturer:** Contact your supplier or distributor. Consult latest *Chemical Week Buyers' Guide*<sup>(73)</sup> for a suppliers list.

**Cautions:** Acetone vapor is a dangerous fire and explosion hazard. High vapor concentrations may produce narcosis (unconsciousness). Prolonged or repeated skin contact causes dryness, irritation, and mild dermatitis.

R	1	NFPA
I	1	
S	1*	
K	3	
* Slight skin absorption		
HMIS		
H	1	
F	3	
R	0	
PPE*		
* Sec. 8		

### Section 2. Ingredients and Occupational Exposure Limits

Acetone, 99.5% plus 0.5% water

#### 1991 OSHA PELs \*

8-hr TWA: 750 ppm (1800 mg/m<sup>3</sup>)

15-min STEL: 1000 ppm (2400 mg/m<sup>3</sup>)

#### 1990 IDLH Level

20,000 ppm

#### 1990 NIOSH REL

TWA: 250 ppm (590 mg/m<sup>3</sup>)

#### 1992-93 ACGIH TLVs

TWA: 750 ppm (1780 mg/m<sup>3</sup>)

STEL: 1000 ppm (2380 mg/m<sup>3</sup>)

#### 1990 DFG (Germany) MAK

1000 ppm (2400 mg/m<sup>3</sup>)

Category IV: Substances eliciting very weak effects (MAK >500 mL/m<sup>3</sup>)

Peak: 2000 ppm, 60 min, momentary value†, 3 peaks/shift

#### 1985-86 Toxicity Data †

Human, eye: 500 ppm

Human, inhalation, TC<sub>50</sub>: 500 ppm produced olfaction effects, conjunctival irritation, and other changes involving the lungs, thorax, or respiration.

Rat, oral, LD<sub>50</sub>: 5800 mg/kg altered sleep time and produced tremors.

Mammal, inhalation, TC<sub>50</sub>: 31500 µg/m<sup>3</sup>/24 hr administered to pregnant female from the 1st to 13th day of gestation produced effects on fertility (post-implantation mortality).

\* In the cellulose acetate fiber industry, enforcement of the OSHA TWA for "doffers" was stayed on 9/5/89 until 9/1/90; the OSHA STEL does not apply to that industry.

† Momentary value is a level which the concentration should never exceed.

‡ See NIOSH, RTECS (AL3150000), for additional irritation, mutation, reproductive, and toxicity data.

### Section 3. Physical Data

Boiling Point: 133.2 °F (56.2 °C) at 760 mm Hg

Freezing Point: -139.6 °F (-95.35 °C)

Vapor Pressure: 180 mm Hg at 68 °F (20 °C), 400 mm Hg at 103.1 °F (39.5 °C)

Saturated Vapor Density (Air = 1.2 kg/m<sup>3</sup>, 0.075 lb/ft<sup>3</sup>): 1.48 kg/m<sup>3</sup>, .093 lb/ft<sup>3</sup>

Refractive Index: 1.3588 at 20 °C

Appearance and Odor: Colorless, highly volatile liquid; sweetish odor.

\* Odor thresholds recorded as a range from the lowest to the highest concentration.

Molecular Weight: 58.08

Specific Gravity: 0.7899 at 20 °C/4 °C

Water Solubility: Soluble

Other Solubilities: Alcohol, benzene, dimethyl formamide, chloroform, ether, and most oils.

Odor Threshold: 47.5 mg/m<sup>3</sup> (low), 1613.9 mg/m<sup>3</sup> (high)\*

### Section 4. Fire and Explosion Data

Flash Point: 0 °F (-18 °C), CC

Autoignition Temperature: 869 °F (465 °C)

LEL: 2.6% v/v

UEL: 12.8% v/v

**Extinguishing Media:** Do not extinguish fire unless flow can be stopped. For small fires, use dry chemical, carbon dioxide (CO<sub>2</sub>), water spray or alcohol-resistant foam. For large fires, use water spray, fog, or alcohol-resistant foam. Use water in flooding quantities as fog because solid streams may be ineffective. **Unusual Fire or Explosion Hazards:** Acetone is a dangerous fire and explosion hazard; it is a Class IB flammable liquid. Vapors may travel to a source of ignition and flash back, fire-exposed containers may explode, and a vapor explosion hazard may exist indoors, outdoors, or in sewers. **Special Fire-fighting Procedures:** Because fire may produce toxic thermal decomposition products, wear a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure-demand or positive-pressure mode. Structural firefighters' protective clothing provides limited protection. If feasible, remove all fire-exposed containers. Otherwise, apply cooling water to sides of containers until well after fire is extinguished. If the fire becomes uncontrollable or container is exposed to direct flame, consider evacuation of a one-third mile radius. In case of rising sound from venting safety device or any discoloration of tank during fire, withdraw immediately. For massive cargo fires, use unmanned hose holder or monitor nozzles. Do not release runoff from fire control methods to sewers or waterways.

### Section 5. Reactivity Data

**Stability/Polymerization:** Acetone is stable at room temperature in closed containers under normal storage and handling conditions. Hazardous polymerization cannot occur. **Chemical Incompatibilities:** Acetone may form explosive mixtures with hydrogen peroxide, acetic acid, nitric acid, nitric acid + sulfuric acid, chromic anhydride, chromyl chloride, nitrosyl chloride, hexachloromelamine, nitrosyl perchlorate, nitryl perchlorate, permonosulfuric acid, thiodiglycol + hydrogen peroxide. Acetone reacts vigorously with oxidizing materials and ignites on contact with activated carbon, chromium trioxide, dioxxygen difluoride + carbon dioxide, and potassium-*tert*-butoxide. Other incompatibles include air, bromoform, bromine, chloroform + alkalis, trichloromelamine, and sulfur dichloride. **Conditions to Avoid:** Keep acetone away from plastic eyeglass frames, jewelry, pens, pencils, and rayon garments. **Hazardous Products of Decomposition:** Thermal oxidative decomposition of acetone can produce CO<sub>2</sub> and carbon monoxide (CO).

### Section 6. Health Hazard Data

**Carcinogenicity:** The IARC,<sup>(164)</sup> NTP,<sup>(169)</sup> and OSHA<sup>(164)</sup> do not list acetone as a carcinogen. **Summary of Risks:** Acetone has been placed among solvents of comparatively low acute and chronic toxicities. In industry, the most common effects reported are headache from prolonged vapor inhalation and skin irritation resulting from its defatting action. Exposures to less than 1000 ppm acetone vapor produces only slight eye, nose, and throat irritation. Acetone does not have sufficient warning properties to prevent repeated exposures. It is narcotic at high concentrations, i.e., above 2000 ppm. Concentrations above 12000 ppm cause loss of consciousness.

Continue on next page

**Section 6. Health Hazard Data, continued**

**Medical Conditions Aggravated by Long-Term Exposure:** None reported. **Target Organs:** Respiratory and central nervous systems, skin. **Primary Entry Routes:** Inhalation, skin and eye contact, ingestion. Liquid acetone is slowly absorbed through the skin. **Acute Effects:** Human systemic effects by inhalation include eye, nose and throat irritation; nausea and vomiting; changes in EEG (electroencephalogram) and carbohydrate metabolism; muscle weakness; drunken behavior; mental confusion and visual disturbance. In extreme cases, breathing high concentrations may produce coma. Human systemic effects by ingestion include gastrointestinal irritation, kidney damage (often indicated by albumin and red and white blood cells in the urine), liver damage (indicated by high levels of urobilin and early appearance of bilirubin), coma, metabolic changes, and systemic effects described for inhalation. Direct eye contact by liquid acetone may produce painful burning and stinging; watering of eyes; conjunctival inflammation; and corneal injury. Skin contact produces a cold feeling, dryness, and mild irritation. **Chronic Effects:** Cases of chronic poisoning resulting from prolonged exposure to low concentrations of acetone are rare. Workers exposed to 1000 ppm, 3 hrs per day for 7-15 yrs, complained of dizziness, asthenia (lack or loss of strength), and chronic inflammation of the airways, stomach, and duodenum. Prolonged or repeated skin contact with liquid acetone may defat the skin and cause eczematoid dermatitis.

**FIRST AID**

**Eyes:** Do not allow victim to rub or keep eyes tightly shut. Gently lift eyelids and flush immediately and continuously with flooding amounts of water until transported to an emergency medical facility. Consult a physician immediately. **Skin:** Quickly remove contaminated clothing. Rinse with flooding amounts of water for at least 15 min. Wash exposed area with soap and water. For reddened or blistered skin, consult a physician. Carefully dispose of contaminated clothing because it may pose a fire hazard. **Inhalation:** Remove exposed person to fresh air, monitor for respiratory distress, and administer 100% humidified supplemental oxygen as needed. **Ingestion:** Never give anything by mouth to an unconscious or convulsing person. Contact a poison control center. Unless the poison control center advises otherwise, have that conscious and alert person drink 1 to 2 glasses of water, then induce vomiting. **After first aid, get appropriate in-plant, paramedic, or community medical support.** **Note to Physicians:** In symptomatic patients, monitor serum and urine acetone, fluid intake, blood glucose, and arterial pH. Because of the prolonged elimination half-life of acetone, the symptomatic patient may need medical supervision for many hours (up to 30 hrs). Patients may develop hyperglycemia and ketosis mimicking acute diabetic coma. The hyperglycemia may persist for several days following acute exposure.

**Section 7. Spill, Leak, and Disposal Procedures**

**Spill/Leak:** Notify safety personnel, evacuate all unnecessary personnel, remove all heat and ignition sources, and provide adequate ventilation. Cleanup personnel should protect against inhalation and skin or eye contact. If feasible and without risk, stop leak. Use water spray to reduce vapor, but it may not prevent ignition in closed spaces. For small spills, take up with sand or other noncombustible absorbent material and using nonsparking tools, place into containers for later disposal. For large spills, dike far ahead of liquid spill for later disposal. Do not release to sewers or waterways. Follow applicable OSHA regulations (29 CFR 1910.120). **Environmental Toxicity:** LC<sub>50</sub> *Salmo gairdneri* (rainbow trout): 5540 mg/L/96 hr at 54 °F (12 °C). LC<sub>50</sub> (oral) Ring-necked pheasant: >40,000 ppm. **Environmental Degradation:** Acetone biodegrades when released into the environment. The biological oxygen demand for 5 days (BOD<sub>5</sub>) is 46-55%. **Soil Absorption/Mobility:** Acetone volatilizes, leaches, and biodegrades if released on soil. **Disposal:** Acetone is a good candidate for fluidized bed, rotary kiln incineration, or catalytic oxidation. Contact your supplier or a licensed contractor for detailed recommendations. Follow applicable Federal, state, and local regulations.

**EPA Designations**

Listed as a RCRA Hazardous Waste (40 CFR 261.33): Hazardous Waste No. U002 (Ignitability), (40 CFR 261.31): F003 (spent solvent)  
Listed as a CERCLA Hazardous Substance\* (40 CFR 302.4): Final Reportable Quantity (RQ), 5000 lb (2270 kg) [\* per Clean Water Act, Sec. 311(b)(4)]

SARA Extremely Hazardous Substance (40 CFR 355): Not listed

Listed as a SARA Toxic Chemical (40 CFR 372.65)

**OSHA Designations**

Listed as an Air Contaminant (29 CFR 1910.1000, Table Z-1-A)

**Section 8. Special Protection Data**

**Goggles:** Wear protective eyeglasses or chemical safety goggles, per OSHA eye- and face-protection regulations (29 CFR 1910.133). Because contact lens use in industry is controversial, establish your own policy. **Respirator:** Seek professional advice prior to respirator selection and use. Follow OSHA respirator regulations (29 CFR 1910.134) and, if necessary, wear a MSHA/NIOSH-approved respirator. Select respirator based on its suitability to provide adequate worker protection for given working conditions, level of airborne contamination, and presence of sufficient oxygen. For concentrations < 1000 ppm, wear any chemical cartridge respirator with organic vapor cartridge(s) and wear eye protection to avoid irritation or damage. For concentrations < 6250 ppm, wear any supplied-air respirator operated in a continuous-flow mode. For concentrations < 12,500 ppm, wear any air-purifying, full-facepiece respirator (gas mask) with a chin-style, front- or back-mounted organic vapor canister. For concentrations < 20,000 ppm, wear any supplied-air respirator that has a full facepiece and is operated in a pressure-demand or other positive-pressure mode. For emergency or nonroutine operations (cleaning spills, reactor vessels, or storage tanks), wear an SCBA. **Warning!** Air-purifying respirators do not protect workers in oxygen-deficient atmospheres. If respirators are used, OSHA requires a written respiratory protection program that includes at least: medical certification, training, fit-testing, periodic environmental monitoring, maintenance, inspection, cleaning, and convenient, sanitary storage areas. **Other:** Wear chemically protective gloves, boots, aprons, and gauntlets to prevent prolonged or repeated skin contact. Polyethylene/ethylene vinyl alcohol, Teflon, or butyl rubber with breakthrough times > 8 hr is recommended for PPE. **Ventilation:** Provide general and local exhaust ventilation systems to maintain airborne concentrations below OSHA PELs (Sec. 2). Local exhaust ventilation is preferred because it prevents contaminant dispersion into the work area by controlling it at its source.<sup>(103)</sup> **Safety Stations:** Make available in the work area emergency eyewash stations, safety/quick-drench showers, and washing facilities. **Contaminated Equipment:** Separate contaminated work clothes from street clothes. Launder before reuse. Remove this material from your shoes and clean personal protective equipment. **Comments:** Never eat, drink, or smoke in work areas. Practice good personal hygiene after using this material, especially before eating, drinking, smoking, using the toilet, or applying cosmetics.

**Section 9. Special Precautions and Comments**

**Storage Requirements:** Store in closed containers in a cool, dry well-ventilated area away from heat, sparks, flames, and other incompatibles. Keep large stocks away from inhabited buildings. Use non-sparking tools to open containers. Keep dry chemical or CO<sub>2</sub> extinguishers on hand in case of fire. **Engineering Controls:** To reduce potential health hazards, use sufficient dilution or local exhaust ventilation to control airborne contaminants and to maintain concentrations at the lowest practical level. To prevent static sparks, electrically ground and bond all containers and equipment during fluid transfer. For bulk storage rooms, install electrical equipment, Class I, Group D. **Administrative Controls:** Consider preplacement and periodic medical examinations with emphasis on the skin and respiratory tract. Also consider liver and kidney function tests and urinalysis.

**Transportation Data (49 CFR 172.101)**

<b>DOT Shipping Name:</b> Acetone	<b>Packaging Authorizations</b>	<b>Quantity Limitations</b>	<b>Vessel Storage Requirements</b>
<b>DOT Hazard Class:</b> 3	a) Exceptions: 173.150	a) Passenger, Aircraft, or Railcar: 5L	<b>Vessel Stowage:</b> B
<b>ID No.:</b> UN1090	b) Non-bulk Packaging: 173.202	b) Cargo Aircraft Only: 60L	<b>Other:</b> --
<b>DOT Packaging Group:</b> II	c) Bulk Packaging: 173.242		
<b>DOT Label:</b> Flammable Liquid			
<b>Special Provisions (172.102):</b> T8.			

**MSDS Collection References:** 26, 73, 100, 101, 103, 124, 126, 127, 132, 133, 136, 139, 140, 148, 149, 153, 159, 163, 164, 167, 168, 171, 174, 176, 180  
**Prepared by:** MJ Wurth, BS; **Industrial Hygiene Review:** PA Roy, MPH, CIH; **Medical Review:** AC Darlington, MPH, MD



**ATTACHMENT B**  
**NIOSH METHODS FOR PCBs**

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mixture:  $C_{12}H_{10-x}Cl_x$   
[where  $x = 1$  to  $10$ ]

MW: ca. 258 (42% Cl ;  $C_{12}H_7Cl_2$ );  
ca. 326 (54% Cl ;  $C_{12}H_5Cl_5$ )

CAS: Table 1

RTECS: Table 1

METHOD: 5503, Issue 2

EVALUATION: PARTIAL

Issue 1: 15 February 1984

Revision #1: 15 August 1987

Issue 2: 15 August 1994

OSHA : 1 mg/m<sup>3</sup> (42% Cl);  
0.5 mg/m<sup>3</sup> (54% Cl)  
NIOSH: 0.001 mg/m<sup>3</sup>/10 h (carcinogen)  
ACGIH: 1 mg/m<sup>3</sup> (42% Cl) (skin)  
0.5 mg/m<sup>3</sup> (54% Cl) (skin)

PROPERTIES: 42% Cl: BP 325 to 366 °C; MP -19 °C;  
d 1.38 g/mL @ 25 °C;  
VP 0.01 Pa ( $8 \times 10^{-5}$  mm Hg;  
1 mg/m<sup>3</sup>) @ 20 °C  
54% Cl: BP 365 to 390 °C; MP 10 °C;  
d 1.54 g/mL @ 25 °C; VP  
0.0004 Pa ( $3 \times 10^{-6}$  mm Hg;  
0.05 mg/m<sup>3</sup>) @ 20 °C

SYNONYMS: PCB; 1,1'-biphenyl chloro; chlorodiphenyl, 42% Cl (Aroclor 1242); and 54% Cl (Aroclor 1254)

SAMPLING		MEASUREMENT	
SAMPLER:	FILTER + SOLID SORBENT (13-mm glass fiber + Florisil, 100 mg/50 mg)	TECHNIQUE:	GAS CHROMATOGRAPHY, ECD ( $^{63}Ni$ )
FLOW RATE:	0.05 to 0.2 L/min or less	ANALYTE:	polychlorobiphenyls
VOL-MIN:	1 L @ 0.5 mg/m <sup>3</sup>	DESORPTION:	filter + front section, 5 mL hexane; back section, 2 mL hexane
-MAX:	50 L	INJECTION VOLUME:	4- $\mu$ L with 1- $\mu$ L backflush
SHIPMENT:	transfer filters to glass vials after sampling	TEMPERATURE-INJECTION:	250 to 300 °C
SAMPLE STABILITY:	unknown for filters; 2 months for Florisil tubes [1]	-DETECTOR:	300 to 325 °C
BLANKS:	2 to 10 field blanks per set	-COLUMN:	180 °C
ACCURACY		CARRIER GAS:	N <sub>2</sub> , 40 mL/min
RANGE STUDIED:	not studied	COLUMN:	glass, 1.8 m x 2-mm ID, 1.5% OV-17/1.95% QF-1 on 80/100 mesh Chromosorb WHP
BIAS:	none identified	CALIBRATION:	standard PCB mixture in hexane
OVERALL PRECISION ( $\bar{S}_r$ ):	not evaluated	RANGE:	0.4 to 4 $\mu$ g per sample [2]
ACCURACY:	not determined	ESTIMATED LOD:	0.03 $\mu$ g per sample [2]
		PRECISION ( $\bar{S}_p$ ):	0.044 [1]

APPLICABILITY: The working range is 0.01 to 10 mg/m<sup>3</sup> for a 40-L air sample [1]. With modifications, surface wipe samples may be analyzed [3,4].

INTERFERENCES: Chlorinated pesticides, such as DDT and DDE, may interfere with quantification of PCB. Sulfur-containing compounds in petroleum products also interfere [5].

OTHER METHODS: This method revises methods S120 [6] and P&CAM 244 [1]. Methods S121 [7] and P&CAM 253 [8] for PCB have not been revised.



**REAGENTS:**

1. Hexane, pesticide quality.
2. Florisil, 30/48 mesh sieved from 30/60 mesh. After sieving, dry at 105 °C for 45 min. Mix the cooled Florisil with 3% (w/w) distilled water.
3. Nitrogen, purified.
4. Stock standard solution of the PCB in methanol or isooctane (commercially available).\*

\* See SPECIAL PRECAUTIONS.

**EQUIPMENT:**

1. Sampler: 13-mm glass fiber filter without binders in a Swinnex cassette (Cat. No. SX 0001300, Millipore Corp.) followed by a glass tube, 7 cm long, 6-mm OD, 4-mm ID containing two sections of 30/48 mesh deactivated Florisil. The front section is preceded by glass wool and contains 100 mg and the backup section contains 50 mg; urethane foam between sections and behind the backup section. (SKC 226-39, Supelco ORBO-60, or equivalent) Join the cassette and Florisil tube with PVC tubing, 3/8" L x 9/32" OD x 5/32" ID, on the outlet of the cassette and with another piece of PVC tubing, 3/4" L x 5/16" OD x 3/16" ID, complete the union.
2. Personal sampling pump, 0.05 to 0.2 L/min, with flexible connecting tubing.
3. Tweezers.
4. Vials, glass, 4- and 7-mL, with aluminum or PTFE-lined caps
5. Gas chromatograph, electron capture detection ( $^{63}\text{Ni}$ ), integrator and column (page 5503-1).
6. Volumetric flasks, 10-mL and other convenient sizes for preparing standards.
7. Syringe, 10- $\mu\text{L}$ .

**SPECIAL PRECAUTIONS:** Avoid prolonged or repeated contact of skin with PCB and prolonged or repeated breathing of the vapor [9-11].

**SAMPLING:**

1. Calibrate each personal sampling pump with a representative sampler in line.
2. Break the ends of the Florisil tube immediately before sampling. Connect Florisil tube to Swinnex cassette and attach sampler to personal sampling pump with flexible tubing.
3. Sample at an accurately known flow rate between 0.05 and 0.2 L/min for a total sample size of 1 to 50 L.  
NOTE: At low PCB concentrations, the sampler was found to be efficient when operated at flow rates up to 1 L/min, for 24 hours [4]. Under these conditions, the limit of detection was 0.02  $\mu\text{g}/\text{m}^3$ .
4. Transfer the glass fiber filters to 7-mL vials. Cap the Florisil tubes with plastic (not rubber) caps and pack securely for shipment.

**SAMPLE PREPARATION:**

5. Place the glass wool and 100-mg Florisil bed in the same 7-mL vial in which the filter was stored. Add 5.0 mL hexane.
6. In a 4-mL vial, place the 50-mg Florisil bed including the two urethane plugs. Add 2.0 mL hexane.
7. Allow to stand 20 min with occasional agitation.

**CALIBRATION AND QUALITY CONTROL:**

8. Calibrate daily with at least six working standards over the range 10 to 500 ng/mL PCB.
  - a. Add known amounts of stock standard solution to hexane in 10-mL volumetric flasks and dilute to the mark.
  - b. Analyze together with samples and blanks (steps 11 and 12).
  - c. Prepare calibration graph (sum of areas of selected peaks vs. ng PCB per sample).
9. Determine desorption efficiency (DE) at least once for each lot of glass fiber filters and Florisil used for sampling in the calibration range (step 8). Prepare three tubes at each of five levels plus three media blanks.
  - a. Remove and discard back sorbent section of a media blank Florisil tube.
  - b. Inject known amounts of stock standard solution directly onto front sorbent section and onto a media blank filter with a microliter syringe.
  - c. Cap the tube. Allow to stand overnight.
  - d. Desorb (steps 5 through 7) and analyze together with working standards (steps 11 and 12).
  - e. Prepare a graph of DE vs.  $\mu\text{g}$  PCB recovered.
10. Analyze three quality control blind spikes and three analyst spikes to ensure that the calibration graph and DE graph are in control.

**MEASUREMENT:**

11. Set gas chromatograph according to manufacturer's recommendations and to conditions given on page 5503-1. Inject sample aliquot manually using solvent flush technique or with autosampler.
 

NOTE 1: Where individual identification of PCB is needed, a procedure using a capillary column may be used [12].

NOTE 2: If peak area is above the linear range of the working standards, dilute with hexane, reanalyze and apply the appropriate dilution factor in calculations.
12. Sum the areas for five or more selected peaks.

**CALCULATIONS:**

13. Determine the mass,  $\mu\text{g}$  (corrected for DE) of PCB found on the glass fiber filter (W) and in the Florisil front ( $W_f$ ) and back ( $W_b$ ) sorbent sections, and in the average media blank filter (B) and front ( $B_f$ ) and back ( $B_b$ ) sorbent sections.
 

NOTE: If  $W_b > W_f/10$ , report breakthrough and possible sample loss.
14. Calculate concentration, C, of PCB in the air volume sampled, V (L):

$$C = \frac{(W + W_f + W_b - B - B_f - B_b)}{V}, \text{ mg/m}^3.$$

**EVALUATION OF METHOD:**

This method uses 13-mm glass fiber filters which have not been evaluated for collecting PCB. In Method S120, however, Aroclor 1242 was completely recovered from 37-mm glass fiber filters using 15 mL isooctane [8,13,14]. With 5 mL of hexane, Aroclor 1016 was also completely recovered from 100-mg Florisil beds after one-day storage [1]. Thus, with no adsorption effect likely on glass fiber filters for PCB, 5 mL hexane should be adequate to completely extract PCB from combined filters and front sorbent sections. Sample stability on glass fiber filters has not been investigated. Breakthrough volume was >48 L for the Florisil tube at 75% RH in an atmosphere containing 10  $\text{mg/m}^3$  Aroclor 1016 [1].

## REFERENCES:

- [1] NIOSH Manual of Analytical Methods, 2nd ed., V. 1, P&CAM 244, U.S. Department of health, Education, and Welfare, Publ. (NIOSH) 77-157-A (1977).
- [2] User check, Southern Research Institute, NIOSH Sequence #4121-U (unpublished, January 25, 1984).
- [3] Kominsky, J. Applied Ind. Hyg. **1** (4), R-6 (1986).
- [4] NIOSH Health Hazard Evaluation Report, HETA 85-289-1738 (unpublished, 1986).
- [5] Hofstader, R. A., C. A. Bache, and D. J. Lisk. Bull. Environ. Contam. Toxicol., **11**, 136 (1974).
- [6] NIOSH Manual of Analytical Methods, 2nd ed., V. 4, S120, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 78-175 (1978).
- [7] Ibid, V. 2, S121, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-157-B (1977).
- [8] Ibid, Vol. 1, P&CAM 253
- [9] Criteria for a Recommended Standard . . . Occupational Exposure to Polychlorinated Biphenyls, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-225 (1977).
- [10] Current Intelligence Bulletin 7, Polychlorinated Biphenyls (PCBs), U.S. Department of Health and Human Services, Publ. (NIOSH) 78-127 (1975).
- [11] Occupational Diseases, A Guide to Their Recognition, revised ed., 255-256, U.S. Department of Health, Education, and Welfare, Publ. (NIOSH) 77-181 (1978).
- [12] Dunker, J. C. and M. T. J. Hillebrand. Characterization of PCB Components in Clophen Formulations by Capillary GC-MS and GC-ECD Techniques, Environ. Sci. Technol., **17** (8), 449-456 (1983).
- [13] Backup Data Report for S120, prepared under NIOSH Contract 210-76-0123, available as "Ten NIOSH Analytical Methods, Set 2," Order No. Pb 271-464 from NTIS, Springfield, VA 22161.
- [14] NIOSH Research Report-Development and Validation of Methods for Sampling and Analysis of Workplace Toxic Substances, U.S. Department of Health and Human Services, Publ. (NIOSH) 80-133 (1980).
- [15] Hutzinger, O., S. Safe, and V. Zitko. The Chemistry of PCBs, CRC Press, Inc., Cleveland, OH (1974).

## METHOD REVISED BY:

James E. Arnold, NIOSH/DPSE; S120 originally validated under NIOSH Contract 210-76-0123.

Table 1. General Information.

<u>Compound</u>	<u>CAS</u>	<u>RTECS</u>
Polychlorinated Biphenyls	1336-36-3	TQ1350000
Chlorobiphenyl	27323-18-8	DV2063000
Aroclor 1016 (41% Cl)	12674-11-2	TQ1351000
Aroclor 1242 (42% Cl)	53469-21-9	TQ1356000
Aroclor 1254 (54% Cl)	11097-69-1	TQ1360000

Table 2. Composition of some Aroclors [15].

<u>Major Components</u>	<u>Aroclor 1016</u>	<u>Aroclor 1242</u>	<u>Aroclor 1254</u>
Biphenyl	0.1%	<0.1%	<0.1%
Monochlorobiphenyls	1	1	<0.1
Dichlorobiphenyls	20	16	0.5
Trichlorobiphenyls	57	49	1
Tetrachlorobiphenyls	21	25	21
Pentachlorobiphenyls	1	8	48
Hexachlorobiphenyls	<0.1	1	23
Heptachlorobiphenyls	none detected	<0.1	6
Octachlorobiphenyls	none detected	none detected	none detected